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GUIDELINES FOR ASSESSMENT AND ABATEMENT OF ASBESTOS-CONTAINING MATERIALS IN BUILDINGS

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Center for Building Technology
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GUIDELINES FOR ASSESSMENT AND ABATEMENT OF ASBESTOS-CONTAINING MATERIALS IN BUILDINGS

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ABSTRACT

This report presents guidelines for the assessment and abatement of asbestos-containing materials in buildings based on available information. Background information is given on the history and use of asbestos-containing products in buildings, and regulations pertaining to their use. Included are control measures for buildings containing asbestos materials, procedures for determining condition of the materials, and abatement techniques for containment and removal. A summary is presented of recent guide specifications and standards developed by industry, government agencies, and a standards organization which are related to asbestos-containing materials in existing buildings. These documents include guidance for the control, assessment, and abatement of such materials.

Key words: abatement of asbestos; asbestos; buildings; fireproofing; insulation; regulations; structural steel

EXECUTIVE SUMMARY

The Public Buildings Service (PBS) of the General Services Administration (GSA) asked that the National Bureau of Standards (NBS) develop state-of-the-art guidelines for surveying buildings having asbestos-containing materials and for selecting and applying assessment and abatement options. The guidelines are based on available information and include a review of the following: (1) history and use of asbestos-containing materials in buildings; (2) examples of building systems which may affect airborne asbestos fiber levels; (3) related regulations, standards, and guidelines; (4) techniques to evaluate asbestos-containing materials; and (5) abatement techniques.

Asbestos has been widely used because it is a relatively inexpensive material with special chemical, physical, and mechanical properties which make it very desirable for many building applications. The important properties are mechanical strength, fire resistance, flexibility, and good friction and wear characteristics. The use of asbestos fibers for fireproofing and insulating materials for building applications began in England in the early 1930s and continued in the United States through the early 1970s. The literature contains extensive documentation addressing potential health effects associated with exposure to airborne asbestos fibers.[1/]

In occupational areas where asbestos materials are handled or machined directly, the regulatory approach of the Federal Government has been to establish the maximum allowable exposure of workers to asbestos fibers, above which protection is deemed necessary. In the United States, the first occupational exposure level to asbestos was proposed in 1938 by the Public Health Service at 30 fibers per cubic centimeter (f/cc).[2/] This has been reduced over the years to the current U.S. Occupational Safety and Health Administration (OSHA) regulation (29 CFR 1910.1001) which stipulates a maximum exposure level of 2.0 f/cc for fibers greater than 5 µm in length measured on an 8-hour time weighted average (TWA) basis and 10.0 f/cc for 15 minute sampling times. Phase contrast microscopy is the method of measurement required by OSHA. OSHA regulations generally apply in routine occupational asbestos exposure situations at a fixed location. In 1976 the National Institute of Occupational Safety and Health (NIOSH) proposed to OSHA a further reduction to 0.1 f/cc for fibers greater than 5 µm in length measured on an 8-hour TWA basis and 0.5 f/cc for 15 minute sampling times. However, this has not been acted upon by OSHA. The applicability of current OSHA fiber exposure limits to the general population where lower asbestos fiber levels exist (such as occupants of buildings where asbestos-containing materials have been used for fireproofing and insulation) is subject to much debate. This issue is not addressed in these guidelines. Regulations of the U.S. Environmental Protection Agency (EPA) cover asbestos emissions to

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1/ Since NBS has no medical expertise, there has been no attempt to evaluate this documentation.

2/ The measurement method for determining the fiber concentration and fiber characteristics (e.g. diameter, length) used to establish this level is unknown to the authors of this report.

the outside environment and disposal of asbestos-containing material from job sites.

Various guide specifications have been developed by agencies of the Federal Government and private sector organizations to assist architects, engineers, and building owners in preparing project specifications and contracts for asbestos abatement work. These were used in preparing these guidelines.

Techniques for the evaluation of the condition of asbestos-containing materials in buildings reported herein include: (1) regional surveys of groups of buildings; (2) building inspection procedures; (3) bulk and air sampling techniques; and (4) available methods for evaluating the potential airborne asbestos fiber level in buildings. The regional survey is needed when an organization has a large inventory of buildings and it is necessary to determine which buildings have asbestos-containing material that may require abatement. This is followed by evaluation of buildings identified as containing such materials and includes discussion with building personnel, review of building plans and specifications, review of previous asbestos related activities, and walk-through inspections. If deemed appropriate, sampling activities can be conducted, including bulk sampling of material to determine its asbestos content and air monitoring to determine airborne asbestos fiber levels. The guidelines discuss several proposed methods for evaluating the potential asbestos exposure in buildings; these methods are undergoing analysis and testing.[1/]

The guidelines conclude with a discussion of available asbestos abatement techniques and information available in the current literature on their selection. The selection of an appropriate asbestos abatement solution is generally based on the condition of the asbestos-containing material, its location, the function and occupancy of the work area, and the cost. The two approaches to control exposure of asbestos may be either interim or long-term measures. Long-term measures include containment (encapsulation and enclosure) and removal, while interim measures consist of a management system for asbestos-containing materials (educational programs, periodic inspections, work procedures, dust control, etc.). These methods have various advantages and disadvantages which must be considered in the context of each building in selecting the most appropriate approach.

1/ NBS has not evaluated these methods and does not endorse or disapprove their application.

PREFACE AND ACKNOWLEDGMENTS

This research on the assessment and abatement of asbestos-containing material in buildings was conducted by the Structures Division and the Building Materials Division of the Center for Building Technology, National Engineering Laboratory, National Bureau of Standards (NBS). The work was sponsored by the Public Buildings Service (PBS) of the General Services Administration (GSA) because of a concern about the presence of asbestos-containing materials in buildings. This document provides guidelines, based on currently available information, for surveying asbestos-containing materials in buildings and for selecting and applying assessment and abatement techniques.

Information used in the preparation of this report was collected from several sources: (a) field inspections of GSA buildings; (b) GSA personnel at the central office and regional offices; (c) personnel of other Federal agencies; (d) standards committees; and (e) an extensive literature survey. Three documents were used extensively in the development of this report and the organizations responsible for them are given special acknowledgment. These documents and organizations are the "Management Procedure for Assessment of Friable Asbestos Insulating Materials" developed by the Naval Facilities Engineering Command, and "Asbestos-Containing Materials in School Buildings: A Guidance Document," Parts 1 and 2 prepared by the U.S. Environmental Protection Agency.

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1. INTRODUCTION

Many buildings in the United States have asbestos-containing materials in their construction. Asbestos has been widely used because it is a relatively inexpensive material with special properties which make it very desirable for many building applications. In recent years, potential health effects from asbestos inhalation have been reported in the literature [1-8].[1/], [2/] Federal regulations establish the maximum allowable exposure of workers to asbestos, above which protection is deemed necessary.

The Public Buildings Service (PBS) of the General Services Administration (GSA) asked that the National Bureau of Standards (NBS) develop state-of-the-art guidelines for surveying buildings having asbestos-containing materials and for selecting and applying asbestos abatement options. The guidelines include the following: (1) history and use of asbestos-containing materials in buildings; (2) examples of building systems which may affect airborne asbestos fiber levels; (3) related regulations, standards, and guidelines; (4) evaluation techniques; and (5) abatement techniques.

1.1 HISTORY OF ASBESTOS USE IN BUILDINGS

Asbestos minerals have been used for many purposes because they are relatively inexpensive materials and their fibers have desirable characteristics of durability, flexibility, strength, and resistance to heat and wear [1]. Asbestos fibers have been used in thousands of applications including: materials for roofing, flooring, fireproofing, friction products; reinforcing in cement, pipes, sheets, and coatings; and thermal, electrical, and acoustical insulations. During the five years ending in 1975 the amount of asbestos fiber used in the United States averaged approximately 800,000 tons annually [2]. It has been estimated that about 90 percent of the asbestos used has gone into products or applications which have effectively immobilized the fibers by mixing them with a strong binding material [3]. Fibers may be liberated from these products by cutting or grinding during their fabrication or use. The other ten percent of the asbestos has been used in applications where the fibers may be more easily released.

The major use of asbestos fibers in buildings has been in spray-applied insulation on structural members and walls and ceilings. This sprayed-on material, in loosely bonded friable form, has been applied extensively to structural steel members, such as beams and columns, for fire protection and to walls and ceilings for thermal and acoustic insulation, architectural decoration, and control of condensation. This type of application offered the advantages of rapidly covering large surfaces and irregular surfaces evenly and efficiently without the use of mechanical support or extensive surface preparation.

1/ References are listed in section 6.

2/ Since the National Bureau of Standards has no medical expertise, there has been no attempt to evaluate these references.

The spray application of asbestos fibers for fireproofing and insulation was first used in England in the early 1930s [3]. In the United States, early spray applications were mainly in clubs and restaurants for decorative use and acoustical insulations on ceilings. In 1950, some form of sprayed mineral fiber fireproofing was used in more than half of the multistory buildings constructed in the United States. Fireproofing alone accounted for 40,000 tons of sprayed material in 1968 [3].

Many substitutes for sprayed asbestos materials are currently available. Most of these spray materials contain fibrous glass or nonasbestos mineral fibers along with cement, gypsum, or other binders similar to those used for asbestos. These materials can be used for fireproofing, thermal and acoustic insulation, and decoration.

1.2 CHARACTERISTICS OF ASBESTOS FIBERS

Asbestos is a generic term applied to a group of naturally occurring mineral silicates that are separable into fibers [4]. During the early 1970s the definition of asbestos was changed by court action because of the public and scientific attention to asbestos pollution. The definition accepted by the Minnesota court which set a precedent during the trial of Reserve Mining Company, stated, "asbestos is a generic term for a number of hydrated silicates that, when crushed or processed, separate into flexible fibers made up of fibrils" [5]. The redefinition of fiber as pertaining to asbestos (U.S. District Court, District of Minnesota, Fifth Division, Fall, 1973) that was adopted by most environmental and public health scientists states that, "a fiber is a mineral which is at least three times as long as it is wide" [5]. This definition of fiber eliminated the difficult task of testing the flexibility and the presence of fibril composition of submicroscopic particles, and retained only the shape of the particle as a decisive criterion [5].

The asbestos fibers used in buildings are from asbestiform varieties of silicate minerals. Table 1.1 lists some common silicate minerals and their asbestiform varieties which are the source of asbestos fibers that are used commercially.

Table 1.1 Silicate Minerals and Their Asbestiform Varieties [9]

Mineral	Mineral Group	Asbestiform Variety
Anthophyllite	Amphibole	Anthophyllite asbestos
Cummingtonite-grunerite	Amphibole	Cummingtonite-gunerite asbestos (amosite)
Tremolite-actinolite	Amphibole	Tremolite-actinolite asbestos
Riebeckite	Amphibole	Crocidolite asbestos
Serpentine	Serpentine	Chrysotile asbestos

It is noted that only a very small quantity of the amphibole and serpentine minerals occur as the asbestiform variety of the mineral [9]. The quality of asbestos depends on the mineralogy of the asbestiform variety, the degree of asbestiform development of the fibers, the ratio of asbestiform fibers to acicular crystals or other impurities, and the length and flexibility of the fibers [9]. The characteristics of the asbestos vary with the different asbestiform varieties; however, the commercially used asbestos materials have fibers that are incombustible, have high tensile strength, exhibit good thermal and electrical insulating properties, and have moderate to good chemical resistance [3].

1.2.1 Chrysotile Asbestos

Chrysotile asbestos, although finely fibrous, belongs to the class of silicates with sheet crystal structures. The sheets of the chrysotile minerals are composed of alternating layers of silica tetrahedrons bound together by hydroxyl groups and magnesium ions. The fibrous form of chrysotile asbestos consists of spirally wound tubes which result from the growth pattern of the mineral sheet structure. Chrysotile fibers are very small in diameter, tubular, and very soft and flexible. The average diameter of individual fibrils is less than 0.1 micrometers (μm) [9]. Mineralogical identification and measurement of chrysotile fibers requires a high level of skill and experience.

1.2.2 Amphiboles

Amphiboles have a fibrous nature derived from a chain-like silicate crystal structure. The fibers are larger in diameter than chrysotile fibers, and are straight and solid in nature, and hard and springy. The average amphibole asbestos fibril diameter is less than 0.5 μm [9]. Identification and measurement of chrysotile asbestos minerals are generally more easily made, particularly from air samples, than those of amphibole asbestos because of the structural and chemical differences within the amphibole group. Identification and measurement of amphibole asbestos can be difficult because of the large range of chemical composition and morphology.

1.3 PRODUCTS AND MATERIALS CONTAINING ASBESTOS

The level of fiber release from asbestos-containing materials depends, in general, on the characteristics of the material containing the asbestos fibers. In some materials such as cement-asbestos and vinyl floor tiles, the asbestos fibers are firmly bound or encased. The release of fibers in these materials is generally not considered a problem. However, cutting, sanding, or grinding of materials containing firmly bound or encased fibers will cause some fiber release [5]. Asbestos fibers may be more readily released from soft, loosely bound, or friable materials such as sprayed fireproofing and insulating materials.

Asbestos-containing construction materials have been divided into two major categories: friable materials and woven products; and nonfriable matrix-bonded composite products [5].

1.3.1 Friable Materials and Woven Products

Friable materials have been described by the U.S. Environmental Protection Agency [EPA] as those which can be "crumbled, pulverized, or reduced to powder in the hand" resulting in the release of fibers with minimal applied force or mechanical disturbance [4]. Among woven products, asbestos fibers and other organic and inorganic fibers are used in rovings, yarns, and cords. These fibers are also woven, braided, or knitted into textile products. Binding agents are usually not used in these textile products.

The most commonly used friable materials and woven products containing asbestos are listed in table 1.2. They include insulating material, preformed thermal insulation products, and textile products.

Table 1.2 Friable Materials and Woven Products Containing Asbestos[1/]

Subdivision	Generic Name	Asbestos % by weight	Dates of Use	Binder/Sizing
Friable Insulating Material	spray-applied insulation	1-95	1935-1970	sodium silicate, portland cement, organic binders
Preformed Thermal Insulating Products	batts, blocks, & pipe covering			
	85% magnesia	15	1926-1949	magnesium carbonate
	calcium silicate	6-15	1949-1971	calcium silicate
Textiles[2/]	cloth			
	blankets	100	1910-present	none
	felts	90-95	1920-present	cotton/wool
	blue stripe	80	1920-present	cotton
	red stripe	90	1920-present	cotton
	green stripe	95	1920-present	cotton
	sheet	95-50	1920-present	cotton/wool
	cord/rope/yarn	80-100	1920-present	cotton/wool
	tubing	80-85	1920-present	cotton/wool
	tape/strip	90	1920-present	cotton/wool
	curtains (theater, welding)	60-65	1945-present	cotton

[1/] Table was taken from reference [5].

[2/] The Navy prohibits use of these products when acceptable nonasbestos-containing substitutes have been identified.

1.3.1.1 Friable Insulation Material

Spray-applied or trowelled-on friable insulation material has traditionally been used in building construction for thermal insulation, condensation control, acoustical control, and fireproofing of steel. This type of asbestos-containing insulation was first used by the construction industry in the United States in the mid-1930s. Friable insulating materials containing asbestos were used generally on the surfaces of metal, wood, concrete, brick, and plaster. Spray application methods were devised to reduce the cost and time for installing continuous sheets of material, particularly on irregular surfaces. The major use of sprayed mineral fiber in buildings is for fireproofing. Generally, friable insulating material used in buildings was a blend of 5 to 95 percent asbestos fibers combined with other materials such as mineral wool fibers, vermiculite, sand, bentonite clay binders, or cellulose fibers and other filler materials.

1.3.1.2 Preformed Thermal Insulation Products

Preformed thermal insulation products include batts and blocks for boilers and preformed pipe converings. From 1926 to 1949 chrysotile asbestos fibers were generally used for preformed thermal pipe insulation. This type of insulation contained about 15 percent asbestos and 85 percent magnesium carbonate. From 1949 to 1971 this material contained about 6 to 15 percent asbestos fibers with the remainder calcium silicate [5].

1.3.1.3 Textile Products

Asbestos textile products are durable and have other desirable properties such as electrical insulation, thermal resistance, and acid resistance. For many years the commonly used asbestos textile products were cloth, cord, rope, yarn, tubing, tape, strip, felts, and blankets. The chrysotile asbestos content of these products may vary from 80 to 100 percent. Other fibers normally blended in the products include wool, cotton, crocidolite or amosite asbestos fibers. Asbestos yarns produced by spinning are used as the basic component in the manufacture of rope, tubing, tape and strips. Asbestos cord has been defined as a multi-ply yarn used for electrical element insulation and tying cord for asbestos cloth [5].

Asbestos tape, strip, and tubing have been used for insulating electrical conductors and for wrapping high-temperature pipe joints. Cloth made from asbestos ranges in weight from a few ounces to several pounds per square yard and is woven in a wide variety of styles, textures, grades and thicknesses. Important uses for asbestos cloth have been covering for pipe insulation, electrical insulation, and theater curtains.

1.3.2 Nonfriable Materials

Nonfriable materials have been described [5] as matrix-bonded composite products prepared by mixing fibers with various bonding agents such as starch, glue, plastics, cements, and asphalt. The degree of bond of asbestos fibers within the composite material or the fiber's immobilization covers a wide

range. Release of bonded fibers varies according to use, environmental conditions, and physical damage to which the products are subjected.

Nonfriable matrix-bonded products for buildings have been divided into the following categories: cementitious products, paper products, roofing felts, asbestos compounds, asbestos ebony, flooring tiles and sheet products, wall-coverings, and paints and coatings [5]. The most commonly used nonfriable bonded composite products containing asbestos are listed in table 1.3.

Asbestos cementitious products are composed primarily of portland cement reinforced with chrysotile asbestos fibers. The cement content may vary from about 10 to 75 percent by weight depending on the required properties of the material. Cement-asbestos pipe is generally made using chrysotile and crocidolite asbestos fibers in the ratio by weight of 3 to 1 respectively. The strong asbestos fibers serve to reinforce the cementitious material. Asbestos-cement products are used for many building purposes including siding shingles, flat sheets, pipe, roofing shingles, corrugated sheets, facings for acoustical material, table tops, electrical conduits, and laminated panels. In many cases, asbestos-cement partitions and ceiling panels are accessible to the interior work environment, and thus, subject to damage.

Clapboard, a thin sheet of asbestos-cement material, has been used extensively under siding on wood frame buildings. Clapboard was produced in 1944 and 1945. Asbestos-cement siding shingles have been extensively produced and used on wood frame buildings for many years. Asbestos-cement roofing shingles are available but have not had extensive use. A great deal of asbestos-cement pipe has been used for water mains, sewage and industrial liquid-waste disposal lines, conduits, vent pipes, flues, and chimneys for heaters.

The large variety of paper products made from chrysotile asbestos fibers includes corrugated, indented, reinforced, and millboard products. Asbestos paper has good heat resistance, is chemically inert, and has good electrical and thermal insulating properties. The paper products have been made for about 50 years or more and generally contain 75 to 99 percent asbestos. Sodium silicate is the primary binder for corrugated and indented papers, while for millboard, asbestos fibers are bound with starch, lime, and clay.

Asbestos roofing felts impregnated with asphalt are used to fabricate membranes for waterproofing and weatherproofing the roofs of buildings. Roofing felts or sheets may also be both impregnated with an asphalt and coated with an asphaltic composition. The asbestos fiber content of the felt is 85 percent or greater. Asbestos saturated felts are also used to cover hot steam lines on the outside of buildings.

Asbestos-containing compounds for exterior and interior construction uses may contain either organic or inorganic binders. Examples of products containing organic binders such as linseed oil and asphalt are caulks, sealants, cold applied adhesives, joint compounds, roofing asphalt, mastics, and asphalt tile cement. Inorganic binders are used in plaster, stucco, and grout.

Table 1.3 Nonfriable Matrix Bonded Composite Products Containing Asbestos[1/],[2/]

Subdivision	Generic Name	Asbestos (% by weight)	Dates of Use	Binder/Sizing
Cementitious Products	extrusions	8	1965-1977	portland cement
	panels:			
	corrugated	20-45	1930-present	portland cement
	flat	40-50	1930-present	portland cement
	flexible	30-50	1930-present	portland cement
	flexible perforated	30-50	1930-present	portland cement
	laminated (outer surface)	35-50	1930-present	portland cement
	roof tiles	30-20	1930-present	portland cement
	clapboard & shingles			
	clapboard	12-25	1944-1945	portland cement
	siding shingles	12-14	unknown-present	portland cement
	roofing shingles	32-20	unknown-present	portland cement
	pipe	20-15	1935-present	portland cement
Paper Products	corrugated:			
	high temperature	90	1935-present	sodium silicate
	moderate temperature	70-35	1910-present	starch
	indented	98	1935-present	cotton and organic binder
	millboard	85-85	1925-present	starch, lime, clay
Roofing Felts	smooth surface	10-15	1910-present	asphalt
	mineral surface	10-15	1910-present	asphalt
	shingles	1	1971-1974	asphalt
	pipeline	10	1920-present	asphalt

1/ Table was taken from reference [5].

2/ The Navy prohibits use of these products when acceptable nonasbestos-containing substitutes have been identified.

Table 1.3 (continued)

Subdivision	Generic Name	Asbestos (% by weight)	Dates of Use	Binder/Sizing
Asbestos-Containing Compounds	caulking putties	30	1930-present	linseed oil
	adhesive (cold applied)	5-25	1945-present	asphalt
	joint compound		1945-1975	asphalt
	roofing asphalt	5	unknown-present	asphalt
	mastics	5-25	1920-present	asphalt
	asphalt tile cement	13-25	1959-present	asphalt
	roof putty	10-25	unknown-present	asphalt
	plaster/stucco	2-10	unknown-present	portland cement
	spackles	3-5	1930-1975	starch, casein, synthetic resins
	sealants fire/water	50-55	1935-present	caster oil or polyisobutylene
	cement, insulation	20-100	1900-1973	clay
	cement, finishing	55	1920-1973	clay
	cement, magnesia	15	1926-1950	magnesium carbonate
Asbestos Ebony Products		50	1930-present	portland cement
Flooring Tile and Sheet Goods	vinyl/asbestos tile	21	1950-present	poly(vinyl)-chloride
	asphalt/asbestos tile	26-33	1920-present	asphalt
	sheet goods/ resilient sheet	30	1950-present	dry oils
Wallcovering	vinyl wallpaper	6-8	unknown-present	--
Paints and Coatings	roof coating	4-7	1900-present	asphalt
	air tight	15	1940-present	asphalt

Asbestos ebony products are used in the construction industry in electrical panels and circuitry. These products contain about 50 percent asbestos fibers and portland cement as a binder. With regard to other building products, asphalt floor tile contains about 25-35 percent asbestos fibers and asbestos vinyl tile contains about 20 percent asbestos fibers. The backings of some sheet goods and resilient sheets contain asbestos. Some of the better quality wallcoverings may contain about 7 percent asbestos fibers. Asphaltic exterior paints may contain about 9 percent asbestos fibers. Some coatings used for sealing cracks and joints may contain about 15 percent asbestos fibers.

1.4 AIRBORNE ASBESTOS FIBERS IN BUILDINGS

1.4.1 Methods of Fiber Dispersal

The concentration level of airborne asbestos fibers present at any given time in a building is dependent on three generating mechanisms shown graphically in figure 1.1. These are natural deterioration, impact, and secondary dispersal.

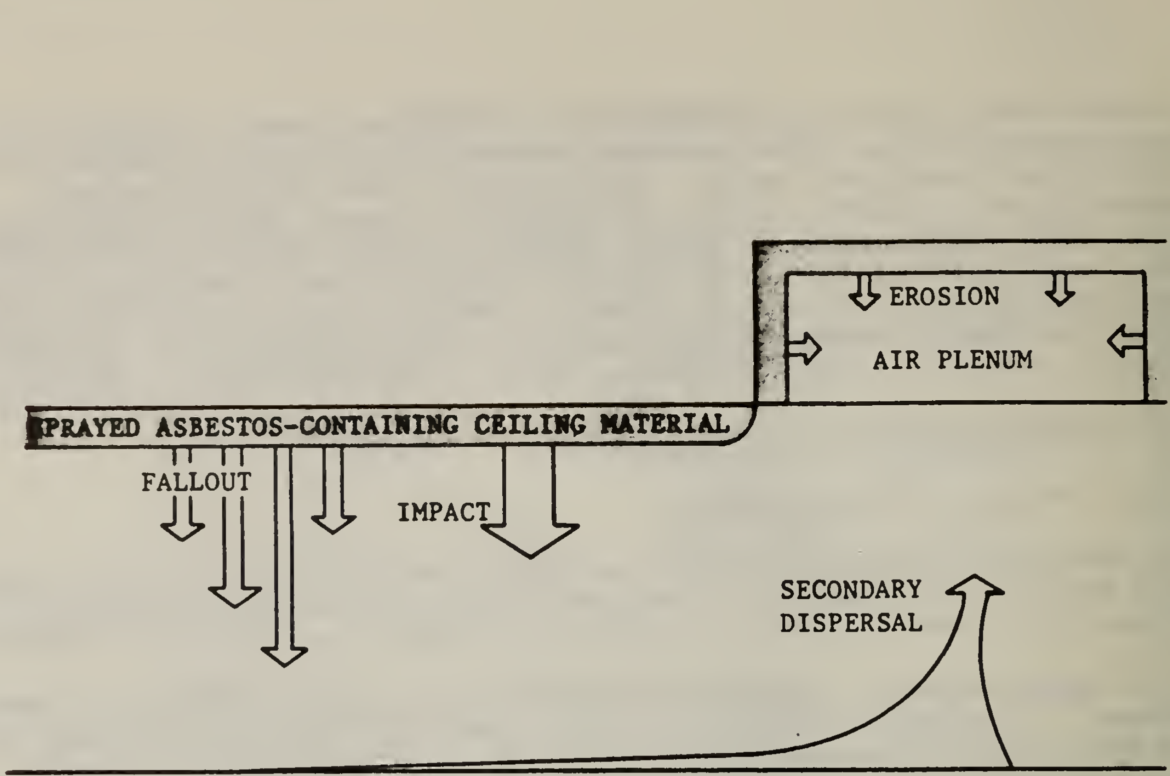
Three groups of people within the building may be subject to airborne asbestos fibers: (1) building occupants; (2) maintenance and operation (M/O) personnel; and (3) contractor personnel. All three groups may be subject to asbestos exposure due to natural deterioration of asbestos-containing materials resulting in the release of fibers into occupied spaces. In addition, fibers can be distributed by the air distribution system. This may occur when asbestos fibers are released into the ceiling air return plenum due to natural deterioration or impact of asbestos-containing materials during M/O activities in the plenum. Exposure may also occur from secondary dispersal of fibers that have already fallen onto interior surfaces. M/O personnel and contractor personnel may be exposed to airborne asbestos when their operations disturb the sprayed-on asbestos-containing fireproofing and insulation materials.

1.4.1.1 Natural Deterioration

Fallout of asbestos fibers may occur by a slow, continuous degradation of the insulating surface and may be accelerated by air movement and vibration which occurs in most buildings. This happens without actual physical disruption of the asbestos fiber containing material and depends on the bond between the adhesive and fibers. Fiber dispersal in fallout may occur at a continuous rate over a long period of time [3]. Factors which affect variations in fallout rate include: vibration of the structure; changes in humidity; air movement from heating, cooling, and ventilating equipment; and air turbulence and vibration caused by human activity. The fallout rate may increase due to aging and degradation of the adhesive component of the insulating or other material. There may be little or no release of fibers from cementitious mixes in good condition, whereas higher rates may occur for deteriorated friable materials.

1.4.1.2 Impact

The level of asbestos fiber release resulting from contact and impact depends upon the accessibility of the fiber-containing material and the likelihood of



MODE	CAUSES	FREQUENCY	FIBER RELEASE RATE
FALLOUT/ EROSION	AIR MOVEMENT, VIBRATION, DETERIORATION	CONSTANT	LOW
IMPACT	MAINTENANCE, ACCIDENTAL IMPACT	OCCASIONAL	HIGH
SECONDARY DISPERSAL	USUAL ACTIVITY CUSTODIAL SERVICE	FREQUENT	LOW TO HIGH

Figure 1.1 Mechanisms resulting in airborne asbestos fibers in buildings[1/]

1/ Figure taken from reference [5].

contact. The function of the building and the activities of the occupants may affect the release of asbestos fibers into the environment. Friable sprayed asbestos surfaces are easily damaged because of their low impact resistance. For these surfaces, even minor physical contact may release fibers. These releases are generally localized and of short duration.

The dispersal of asbestos fibers by contact produces the highest release rates. It has been reported that the level of airborne fiber concentration during routine maintenance and repair activities has, in some cases, exceeded 20 fibers per cubic centimeter (f/cc), and the removal of dry sprayed asbestos material has in reported cases resulted in airborne fiber concentration levels of over 100 f/cc [3][1/]. These levels are considerably higher than those allowed under current federal regulations (see section 3.2).

1.4.1.3 Secondary Dispersal

Reentrainment of fibers which have already settled on surfaces (e.g. above ceiling tiles, on floors and furniture) can occur after initial release by natural deterioration or impact [3]. In addition, particles released from the insulation are subject to possible fragmentation and subsequent reentrainment due to activity in the area. Secondary dispersal is a function of the activity level of a building area and may involve repeated cycles of resuspension and settling.

Fiber counts as high as 5 f/cc have been reported from activity within a building such as custodial work [3][1/]. In cases where settled fibers are present, custodial activities may result in increased levels of airborne fibers. In a library with a deteriorating sprayed asbestos ceiling, continuous dusting of extensive areas of shelving raised the average fiber level for the custodians to 4 f/cc, and to 0.3 f/cc for nearby library users [3][1/].

1.4.2 Aerodynamics of Asbestos Fibers

Dispersed asbestos fibers generally have a length ranging from less than 0.1 µm to some tens of micrometers. Asbestos fibers released into the air will settle downward at a rate depending on their mass, form, axis attitude, and air movement. Fiber characteristics strongly affect settling velocity and total time of suspension. The settling velocity depends mainly upon the fiber diameter and to a lesser extent upon fiber length. Settling time is also affected by the fiber alignment, fiber axis vertical or horizontal, and its aspect ratio (length divided by diameter).

Fibers 1 to 5 µm in length and an aspect ratio of about 5:1 are common in material dispersed from overhead insulation in buildings [3]. The theoretical settling velocities for fibers 5, 2, and 1 µm long having an aspect ratio of 5:1 and with their axis attitude varying between vertical and horizontal, would be 2×10^{-2}, 4×10^{-3}, and 1×10^{-3} cm/s, respectively [3]. The

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[1/] The measurement techniques for determining the fiber concentration and fiber characteristics (e.g., diameter, length) were not reported.

theoretical times needed for these fibers to settle from a 9 ft high ceiling to the floor would be 4, 20, and 80 hours in still air, respectively [3]. Turbulence will increase the settling time and also cause reentrainment of fallen fibers. Figure 1.2 shows the theoretical settling velocities in still air for fibers of varying size, alignment, and aspect ratio.

While fibers are airborne they are able to move laterally with air currents into areas distant from the point of release. Significant levels of contamination have been documented hundreds of meters from the point of release of asbestos fibers [3]. Also, fibers may be transported across contamination barrier systems with the passage of workers during the removal of asbestos-containing materials.

1.4.3 Concentrations of Airborne Asbestos Fibers

EPA has reported that airborne asbestos fiber levels within buildings with deteriorating asbestos-containing material may be significantly greater than outdoor ambient air level [3]. Determinations of fiber levels during periods of quiet activity conditions, such as at night when the building is not occupied, may be misleading [3]. Routine activities in buildings containing sprayed asbestos surfaces may result in higher airborne fiber levels. EPA reports that normal activities in school buildings with accessible sprayed asbestos surfaces may result in indoor airborne asbestos concentrations in the 10 to 50 f/cc range [3][1/]. As mentioned previously, custodial work could result in the disturbance and reentrainment of the accumulations of fibers which were released from sprayed surfaces by natural deterioration and contact. Airborne fiber levels from reentrainment may be higher due to custodial work, depending on cleaning methods and location of the work relative to the occupants. Such activities result in reported airborne asbestos fiber levels that exceed regulatory limits established by the U.S. Occupational Safety and Health Administration (OSHA) given in table 3.1. Table 1.4 gives estimates of airborne asbestos content in buildings based on various types of activities [5].

1/ The measurement technique for determining the fiber concentration and fiber characteristics (e.g., diameter, length) were not reported.

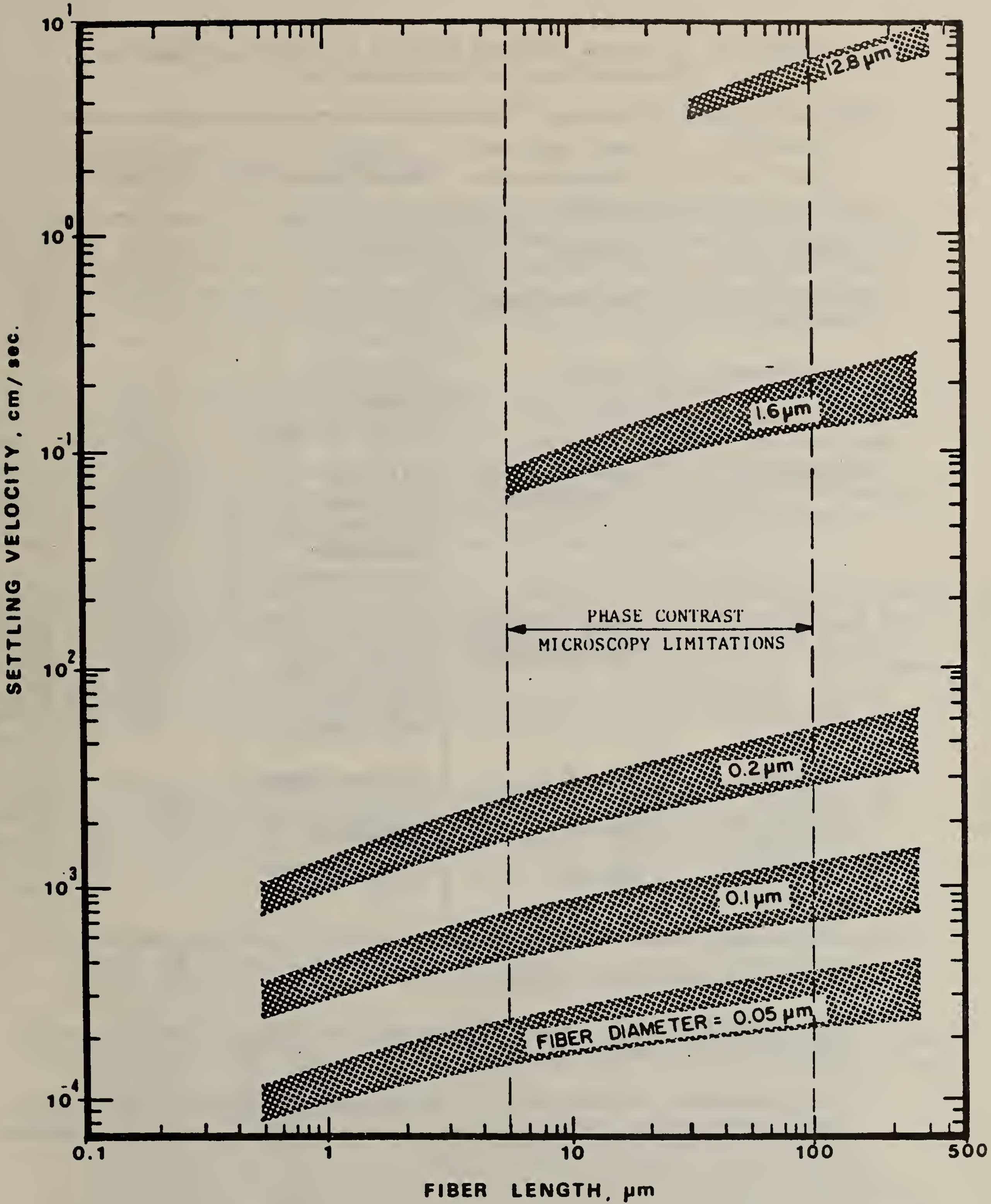


Figure 1.2 Theoretical settling velocities of asbestos fibers[1/]

[1/] Figure taken from reference [5].

Table 1.4 Airborne Asbestos Content in Buildings Based on Various Types of Activities[1/],[2/]

Activity Classification	Main Mode of Contamination	Activity Description	Mean Count[3/] (f/cc)
Quiet	fallout	none	0.0
Nonspecific routine	reentrainment	office	0.4
Maintenance	impact	relamping	1.4
		plumbing	1.2
		cable movement	0.9
Custodial	mixed: impact reentrainment	cleaning	15.5
		dry sweeping	1.6
		dry dusting	4.0
		bystander	0.3
		heavy dusting	2.8
Renovation	mixed: impact reentrainment	ceiling repair	17.7
		tract light	7.1
		hanging light	1.1
		partition	3.1
		pipe lagging	4.1
Vandalism	impact	ceiling damage	12.8
Removal, dry	impact	stripping	40
Removal, wet amended	impact	stripping	2.8

1/ Table was taken from reference [5].

2/ See section 3.2 and appendix A for current Federal regulations for exposure to airborne asbestos fibers.

3/ The measurement techniques for determining the fiber concentration and fiber characteristics (e.g., diameter, length) were not reported.

2. EXAMPLES OF BUILDING SYSTEMS WHICH AFFECT AIRBORNE ASBESTOS FIBER LEVELS

2.1 SPRAY-APPLIED FRIABLE INSULATION

The predominant use of asbestos-containing material in buildings has been the spraying of insulation on structural members and on walls and ceilings. This friable sprayed-on material has been applied extensively to structural steel members such as beams and columns for fire protection and to walls and ceilings for the purpose of providing thermal and acoustic insulation, architectural decoration, and control of condensation.

Structural steel used in buildings suffers a reduction of mechanical properties, such as strength, stiffness and ductility, when exposed to elevated temperatures. Because of this loss of mechanical properties, it must be protected from fire exposure by covering with fireproofing materials. Spray-applied fireproofing containing asbestos was used widely until the early 1970s because it was inexpensive, quick to install, involved only one building trade, and was easily integrated with the overall construction process.

Sprayed applications of asbestos-containing materials have been used extensively for fireproofing of exposed structural steel members and the underside of metal decking in composite concrete/steel floor systems (figure 2.1). The bottom of the floor system can be either exposed (figure 2.2) or enclosed with a dropped ceiling structure to form a plenum (figures 2.1 and 2.3). Vertical steel members (columns, bracing, etc.) are also often coated with fireproofing (figure 2.4).

As discussed previously, fireproofing on structural steel members and other spray applied friable insulation may be subject to natural deterioration and physical damage. While it is difficult to observe natural deterioration, the result of physical damage is generally quite obvious. This damage can be caused by:

A. maintenance and operations work within the ceiling plenum which may cause fireproofing to be dislodged and fall onto the suspended ceiling (figure 2.5).

B. location of asbestos-containing material on vertical surfaces at floor level or on low horizontal surfaces which can be contacted by building occupants (figures 2.4, 2.6 and 2.7).

C. modifications made to the building since construction including: (1) addition of a fire sprinkler system; (2) modifications to the heating, ventilating, and air conditioning (HVAC), electrical, and plumbing systems, (figures 2.8, 2.9, 2.10, and 2.11); and (3) changes to the office partition system (figure 2.12); and

D. contractor carelessness when doing work in the vicinity of asbestos-containing material (figure 2.13).

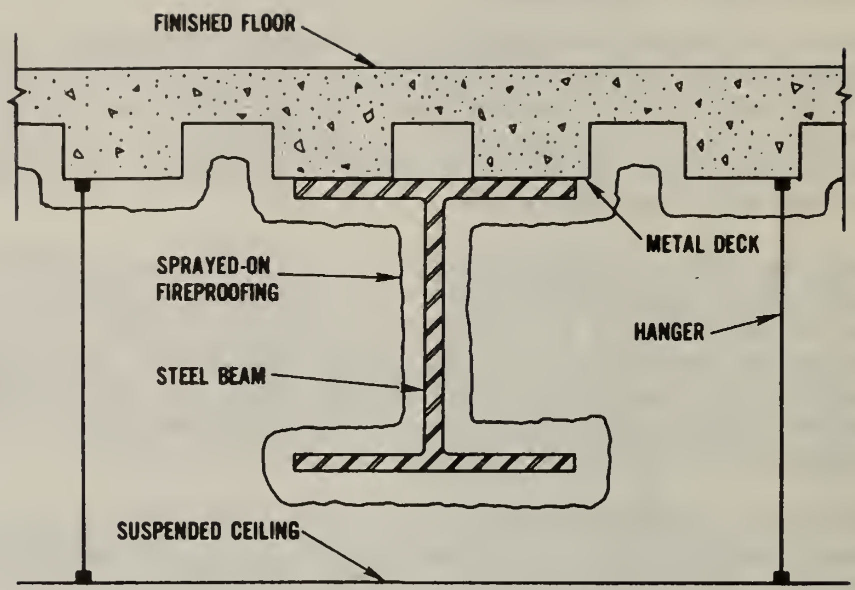


Figure 2.1 Sketch of typical return air plenum configuration with exposed fireproofing on structural steel and deck

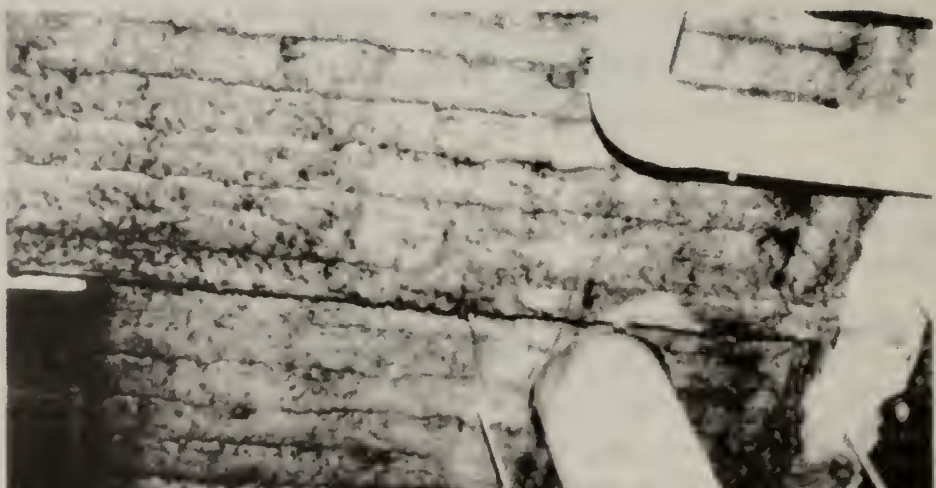


Figure 2.2 Exposed fireproofing on ceiling of mechanical room

Figure 2.3 Typical composite floor system within return air plenum with sprayed-on fireproofing

Figure 2.4 Damaged sprayed-on fireproofing on vertical steel bracing members

Figure 2.5 Dislodged fireproofing lying on suspended ceiling tiles within return air plenum

Figure 2.6 Horizontal structural member easily accessible to building occupants with damaged fireproofing

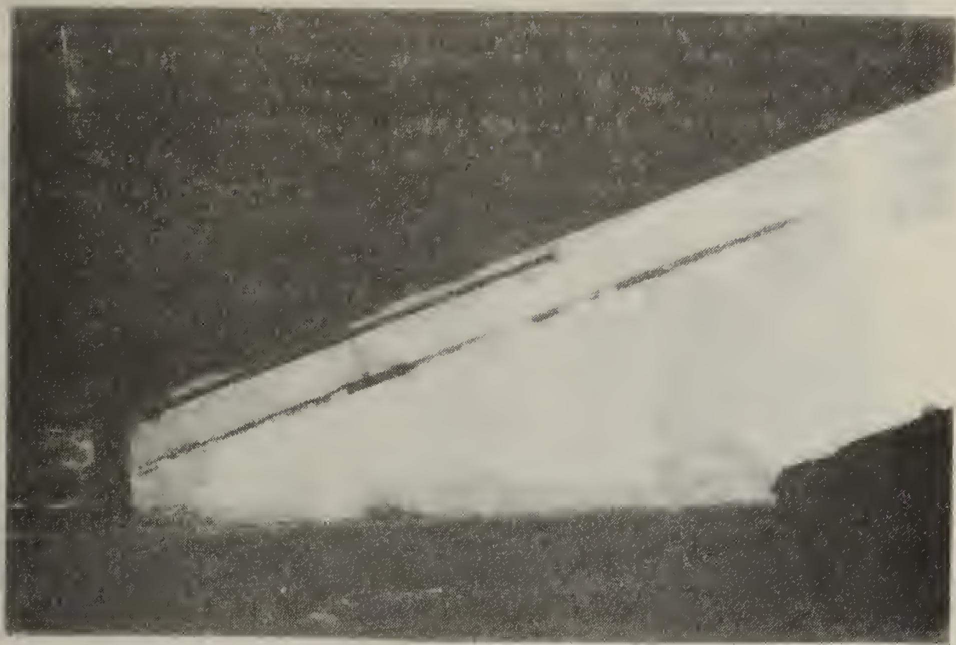


Figure 2.7 Structural bracing member with damaged fireproofing at floor level

Figure 2.8 Fireproofing damaged by addition of hangers during modifications to plumbing and HVAC systems

Figure 2.9 Damage to fireproofing caused by floor penetrations for plumbing system modifications

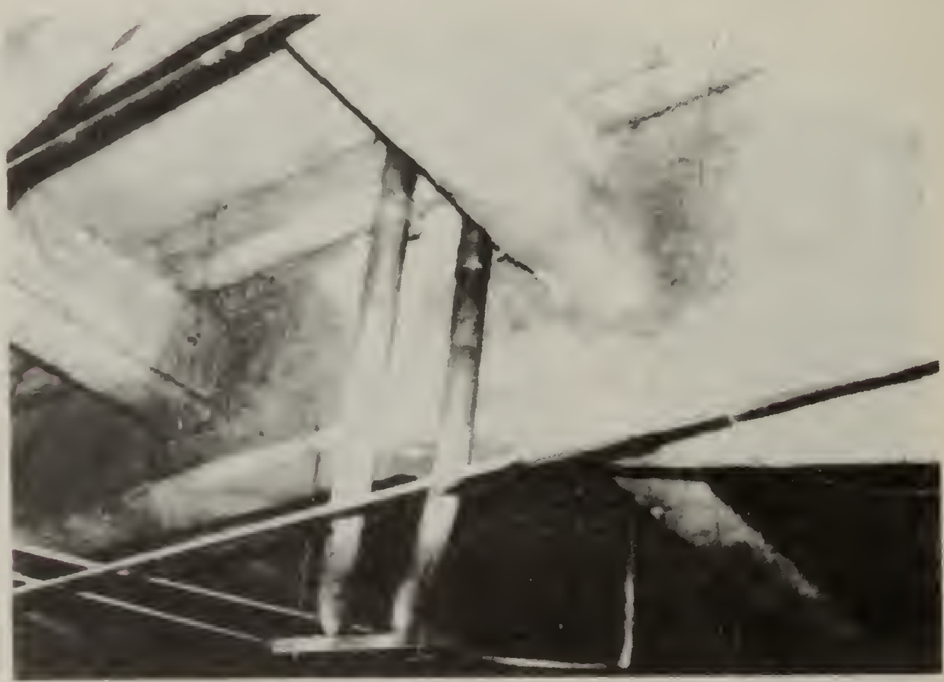


Figure 2.10 Damage to fireproofing on structural steel due to HVAC system modifications

Figure 2.11 Damage to fireproofing on structural steel due to electrical system modifications

Figure 2.12 Damage to fireproofing due to modifications of the vertical partition system

Figure 2.13 Damage to fireproofing due to carelessness while materials were being transported to other areas of the buildings

Elevator motors, fans, and pumps are quite often located on floors or roofs supported by structural steel and steel deck protected with fireproofing. Vibrations caused by such equipment can dislodge fireproofing material or other spray-applied insulation and increase the potential for asbestos fiber dispersal.

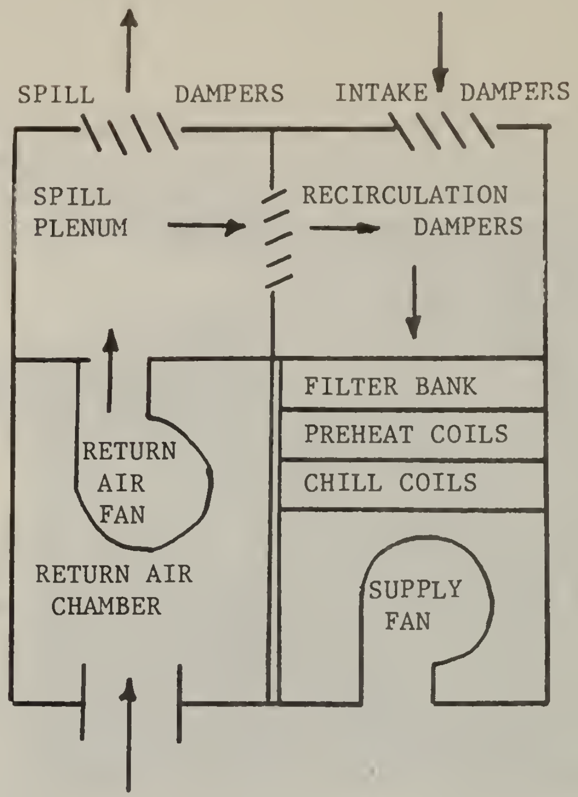
2.2 HEATING, VENTILATING, AND AIR CONDITIONING SYSTEMS (HVAC)

The HVAC system has the potential for circulating asbestos fibers throughout the building if fibers are released from asbestos-containing materials [5]. This is particularly true for buildings where the HVAC system can be characterized as shown on figure 2.14 and discussed below.

Large modern buildings have equipment rooms which take in fresh air and distribute conditioned air to different floors. Depending on the horizontal dimensions of the building, the equipment room and air supply system may be divided into several vertical zones which service different sections of the building. Typically, a high rise building will have one equipment room at approximately mid-height and another at the topmost level of the building. Large fans in the equipment room force the preconditioned air into ducts which contain acoustical insulation. The ducts lead to vertical risers which carry the air to the various floors for distribution by the local supply ducts (figure 2.15). On each floor the exhaust air is either ducted directly to a large vertical riser, or, more likely, the air is exhausted directly into the ceiling plenum between the suspended ceiling and the floor above (figures 2.1 and 2.15). This plenum may contain plumbing, electrical, mechanical, and utility equipment. More importantly, as was previously discussed, the underside of the floor may be coated with sprayed fireproofing which may contain asbestos to provide a fire rating to the structural steel and steel floor deck assembly. The return air exhausted into the plenum contacts the fireproofing with the potential for dislodging fibers and circulating them throughout the building (see figure 2.1).

At several locations within the ceiling plenum, metal ducts conduct the return air into vertical risers. The air is then returned through the vertical risers to the return air chamber where it exhausts into a spill chamber. The vertical risers may contain structural members with fireproofing or thermal insulation with the potential that fibers may be dislodged and circulated throughout the building by the HVAC system. Depending on the temperature of the outside air and the building return air, the return may be entirely exhausted to the outside, or may be recirculated to some degree. Dampers control the degree of air recirculation and the amount of fresh air used. The air to be recirculated passes through recirculation dampers and mixes with fresh air which has been drawn through intake dampers. The intake air is sometimes prefiltered with coarse fiberglass filters. The mixed air is then drawn through the filter bank, which consists of multi-pocketed bags made of fiberglass or other fibrous material (figures 2.14 and 2.16).

The accessibility of the unducted air return plenum to building occupants may affect the dispersal of asbestos fibers. Such accessibility often depends on the type of suspended ceiling construction. This can range from drywall



[1] Taken from reference [6].

Figure 2.14 Typical HVAC system configuration of high-rise buildings[1]

Figure 2.15 Typical air supply and return duct system in ceiling of occupied space (with drop ceiling removed)

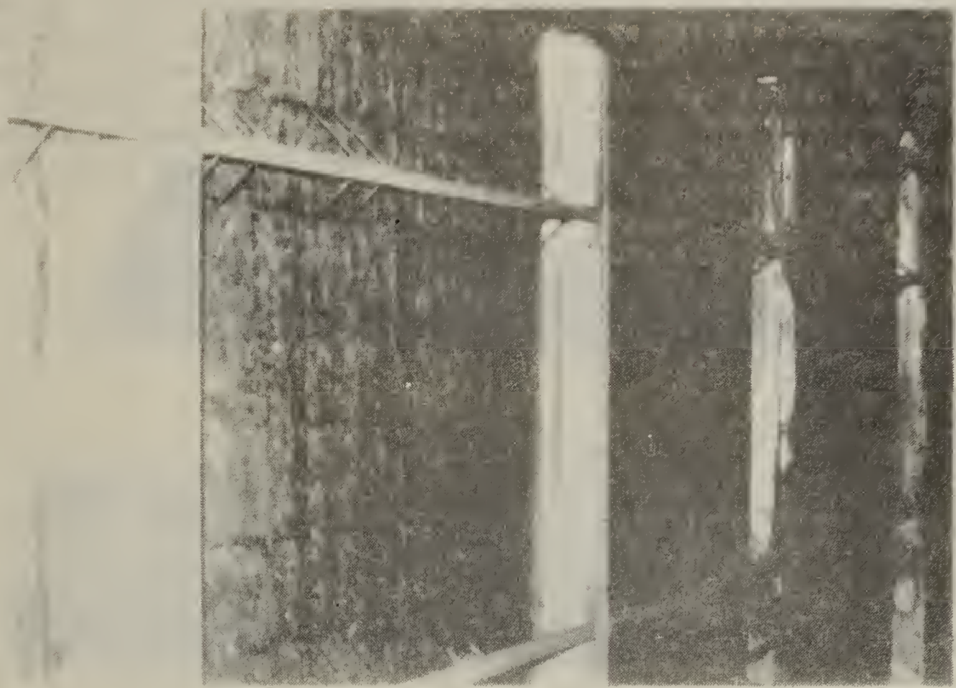


Figure 2.16 Air filter bank in air-intake room

Figure 2.17 Drywall ceiling construction with hole cut for maintenance work in the plenum

construction (figure 2.17) which makes the ceiling inaccessible on a routine basis to lay-in panels which can be easily removed (figure 2.18). Between these two extremes there are various types of suspended panel systems with mechanical interlocks which restrict unwanted access (figure 2.19). Easy-to-remove ceiling panels allow M/O personnel and occupants easy access to an area which may have dislodged fireproofing. However, M/O personnel have more frequent access to the ceiling plenum due to their job functions than building occupants.

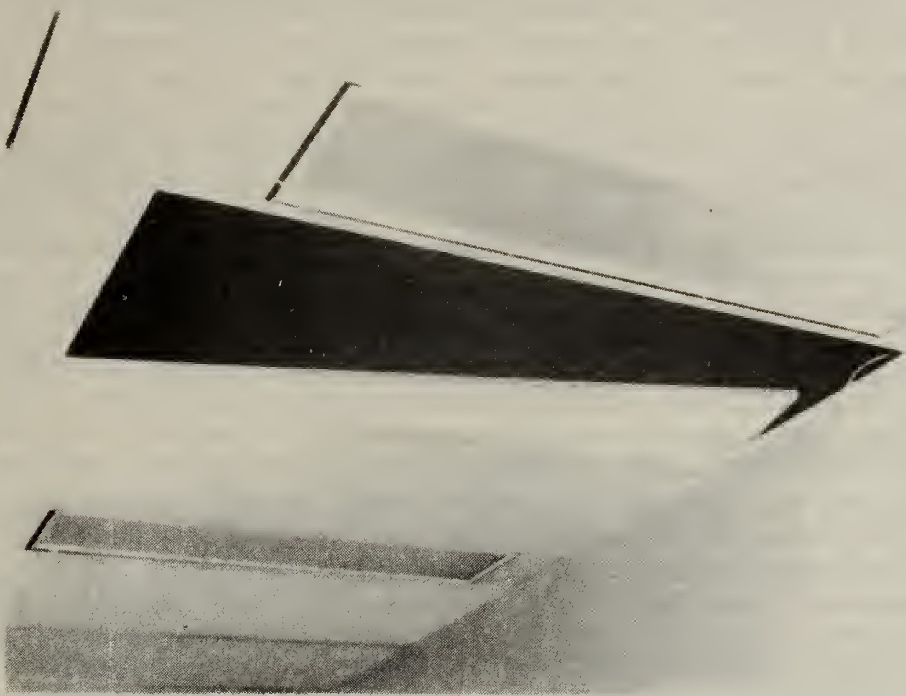


Figure 2.18 Typical drop-in suspended ceiling construction

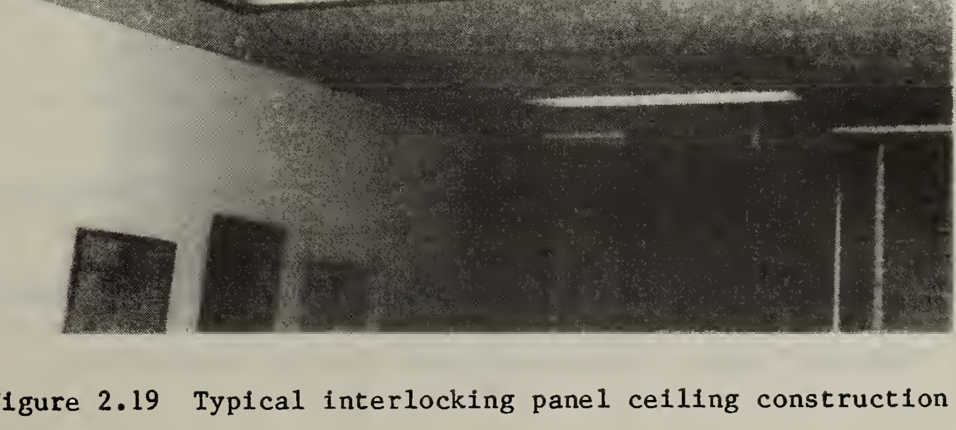


Figure 2.19 Typical interlocking panel ceiling construction

3. REGULATIONS, STANDARDS, AND GUIDELINES RELATED TO ASBESTOS-CONTAINING MATERIALS IN BUILDINGS

3.1 BACKGROUND [5]

The regulatory approach of the Federal Government has been to establish by law the maximum allowable exposure of workers to asbestos, above which protection is deemed necessary. Standards have been based on the number of respirable asbestos fibers (which are greater than a minimum length) suspended in the air. See section 4.3 for a discussion of the measurement methods for analyzing; (1) bulk samples for asbestos content by weight, and (2) air samples for airborne asbestos fiber levels. A discussion of the historical development of regulations related to airborne asbestos fiber levels follows.

3.2 GOVERNMENT REGULATIONS [5]

Table 3.1 presents a historical outline of the reduction of worker exposure to asbestos which has occurred in the United States. The more recent Federal regulations pertaining to sprayed asbestos materials have been issued by EPA and OSHA. In general, OSHA regulations cover occupational asbestos exposure situations at a fixed location. EPA regulations cover emissions to the outside environment and the removal and disposal of material from job sites.

Table 3.1 Historical Outline of Asbestos Standards Related to Worker Exposure1/

Year	Agency	Basis of Standard	Asbestos Exposure Level (f/cc)
1938	U.S. Public Health Service	proposed2/	30
1969	Walsh-Healy Public Contract Act	informed3/	12
1971	OSHA	informed	12
1972	OSHA	informed	5.0
1976	OSHA	informed	2.0
1977-1978	NIOSH	proposed (to OSHA)	0.1

1/ Table based on information from reference [5].

2/ "Proposed" means not incorporated into Federal regulations.

3/ "Informed" means incorporated into Federal regulations.

Asbestos industry regulations were first introduced in the United Kingdom in 1931. These regulations required the adoption of certain precautions aimed at reducing the exposure of workers to asbestos dust [10]. In 1938, the U.S. Public Health Service proposed a maximum exposure level of 30 f/cc[1/]. As environmental issues took on additional importance, the 1970 Occupational Safety and Health Act was passed which emphasized the need for standards to protect the health of workers exposed to potential hazards at their place of work. A standard for occupational exposure to asbestos was included in an OSHA standard published in 1971. The standard, based on a 1969 Federal Standard issued under the Walsh-Healey Public Contracts Act, also included an asbestos exposure limit of 12 f/cc (of fiber length greater than 5 μm)[2/].

This was followed by an OSHA Standard for Exposure to Asbestos Dust published in the Federal Register, Vol. 37, No. 110, on June 7, 1972 (29 CFR 1910.93a). This standard was recodified to 29 CFR 1910.1001 in the Federal Register dated May 28, 1975. This regulation applies to workers handling or exposed to asbestos fibers or material containing asbestos fibers. The regulations stipulated a maximum exposure of 5 f/cc for fibers greater than 5 μm in length over an 8-hour period on a time weighted average (TWA) basis. A level of 10 f/cc for a 15-minute sampling period was the maximum allowed any-time excursion. This standard for occupational exposure also defines methods of compliance with regulations, personal protective equipment including clothing and respiratory protection, methods of measurement of airborne asbestos fibers, signs and labels warning of asbestos hazard, housekeeping methods for fiber control and waste disposal, recordkeeping for monitoring and exposures, and medical examinations.

The original requirement for maximum exposure given in OSHA regulation 29 CFR 1910.1001 was reduced on July 1, 1976 to 2 f/cc for fibers greater than 5 μm in length determined over an 8-hour period on a time weighted average (TWA) basis. Maximum levels for 15-minute sampling times remained at 10 f/cc. Phase contrast microscopy was identified as the method of measurement. (See section 4.3.3.2 for discussion of phase contrast microscopy.) Appendix A contains a summary of these regulations.

There has been considerable discussion concerning the adequacy of the 2 f/cc occupational standard [8]. In December 1976, the National Institute of Occupational Safety and Health (NIOSH) proposed to OSHA a further lowering of airborne asbestos fibers over 5 μm in length to 0.1 f/cc TWA with 0.5 f/cc as the maximum permissible any-time excursion. Phase contrast microscopy was retained as the method of measurement. This NIOSH proposal has not been adopted as a Federal regulation.

Regulations promulgated by the U.S. Environmental Protection Agency on April 6, 1973, apply to the renovation or demolition of structures having asbestos-

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1/ The measurement technique for determining the fiber concentration and fiber characteristics (e.g., diameter, length) are unknown.

2/ The method of measurement for determining fiber concentration is unknown to the authors of this report.

containing materials and to the spraying of materials of not more than 1 percent asbestos (see appendix A). Furthermore, OSHA regulation 29 CRF 1910.1001 for asbestos discussed above specifies procedures for removal and stripping of friable sprayed asbestos fireproofing and insulation materials and requires that EPA be notified when removal is to take place. The required work practices include wetting, containment, container labeling, and disposal of the removed material in an approved sanitary landfill. Fiber levels are not specified but the regulations require that there be no visible emissions exterior to the structure.

Since regulations affecting nearly all aspects of potential exposure to asbestos are being reconsidered by OSHA and EPA, any questions concerning these current regulations should be referred to the agencies' regional offices. EPA and OSHA Regional Offices are listed in appendix B.

Most State and local governments adhere to current EPA and OSHA regulations; however, in instances where the problem is acute or has received public attention, special bylaws or ordinances may have been passed which are more stringent than federal regulations. State departments of health, labor, and environmental protection can provide additional guidance in the event that more stringent state regulations are in effect or if difficulty is experienced in locating an approved disposal site for asbestos-containing debris.

3.3 GUIDE SPECIFICATIONS FOR ASBESTOS ASSESSMENT AND ABATEMENT[1/]

3.3.1 Association of Wall and Ceiling Industries (AWCI)

In December 1981, the Foundation of the Wall and Ceiling Industry of the Association of the Wall/Ceiling Industries-International, Inc. published "Guide Specifications for the Abatement of Asbestos Release from Spray - or Trowel-Applied Materials in Buildings and Other Structures [11]." The guide specifications are intended to assist architects, engineers, and building owners in preparing project specifications and contracts for asbestos abatement work.

The guide specifications were prepared by an Ad Hoc Task Group that included six contractors, two representatives from EPA, and one representative from each of the following organizations: AWCI, Public Works Canada, HUD-FHA, Alberta Labour (Canada), GSA, and OSHA. The guide specification has not been officially adopted or "approved" by the public agencies participating in its development. The authors of the document made an attempt to ensure that the guide specifications reflect the best technology for asbestos abatement currently available. However, they do not claim that use of the specifications will guarantee a risk-free, successful abatement job, and do not take responsibility for any work done using these specifications. The guide specifications point out that technology relating to asbestos abatement is changing rapidly and more advanced techniques may become available.

1/ Inclusion of these documents does not represent NBS endorsement or disapproval of their content.

The guide specifications are intended to be revised to fit the conditions of each particular job. The specifications include actions required by regulations as well as guidance on current work practices. The guidance is based upon experience with abatement procedures and offers procedures for complying with the regulatory requirements.

The guide specifications recommend that building owners and their representatives require that contractors who submit bids for asbestos abatement work demonstrate that they have had experience in such work. It further states that they should require contractors to submit letters of reference from the owners of the buildings where this work was done, and air monitoring data taken during this work. As an alternative to, or in addition to, previous experience, building owners should require of contractors submitting bids that the contractors have successfully completed a training course in asbestos abatement work. If so, the contractors should be required to submit letters from the firm, agency, or association which conducted the training course and a syllabus of the session. Training sessions should include instruction in applicable regulations, work area isolation, worker protection, the selection, use, and maintenance of respirators, proper asbestos abatement techniques, and proper work area decontamination procedures.

3.3.2 Public Buildings Service (GSA)

The Public Buildings Service of GSA has issued Tentative Guide Specifications on Asbestos Abatement Procedures [12]. It covers all work necessary to reduce airborne asbestos fiber concentrations to a required level and to maintain it at or below that level during construction. It also covers procedures for the removal and/or containment of friable asbestos-containing material. The document requires the contractor to assume full responsibility and liability for compliance with all applicable Federal, State, and local regulations pertaining to the protection of workers, visitors to the site, and persons occupying areas adjacent to the site.

3.3.3 Civil Engineering Laboratory (U.S. Navy)

The Civil Engineering Laboratory, Naval Construction Battalion Center, in February 1981 issued Technical Report R883 "Management Procedure for Assessment of Friable Asbestos Insulating Material" [5]. This document provides procedures for evaluating friable asbestos-containing materials. An asbestos "hazard index" is presented for determining if an abatement project should be initiated. The "hazard index" is currently being tested at Naval facilities. The document also includes guidance on proper interim control measures, as well as guidance for selecting and specifying appropriate long-term control measures, standardized safety procedures, and personnel protection during maintenance and control of friable asbestos-containing insulating systems, including their disposal. The long-term control measures emphasize the need for cost-effective alternatives which will meet current fiber pollution restrictions.

Although the document does not present guide specifications for asbestos abatement, it does provide information with regard to the factors to be considered in contract preparations. The document also presents samples of technical

specifications for dry removal, wet removal, and encapsulation of friable asbestos insulating material and asbestos contaminated items. The sample technical specifications were prepared in accordance with EPA, OSHA, and Navy regulations on handling asbestos materials.

3.3.4 Naval Facilities Engineering Command (NAVFAC)

NAVFAC has prepared a draft guide specification NFGS-02075, "Removal and Disposal of Asbestos Materials" [13]. This draft guide specification is intended to be used by Naval personnel as a model in preparing project specifications. It covers the safety procedures and requirements for the removal and disposal of friable asbestos-containing material. Non-friable materials containing asbestos normally do not require special handling and disposal procedures unless such materials are sawn, pulverized, or handled in such a manner that will cause dust and airborne asbestos fibers to be released. If the project contains nonfriable asbestos that is considered to be hazardous due to material condition, then the nonfriable asbestos shall be specified to be removed in accordance with procedures established for friable material.

3.3.5 Office of the Chief of Naval Operations (OPNAV)

On February, 12, 1982 OPNAV issued Instruction 6260.1B, "Control of Asbestos Exposure to Naval Personnel and Environs" [14]. These instructions are intended to enable U.S. Navy personnel to comply with the national safety and health standards for asbestos regarding occupational health and to comply with the National Emmission Standard for asbestos for environmental protection.

3.4 AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM) STANDARDS DEVELOPMENT

3.4.1 ASTM Task Group E06.21.06E on Encapsulation of Building Materials

In ASTM Committee E6 on Performance of Building Constructions, a Task Group on Encapsulation of Building Materials (E06.21.06E) is charged with the development of a Standard Specification for Encapsulating Agents for Friable Asbestos-Containing Building Materials. A draft standard is in preparation and may be changed prior to being adopted as an approved standard. The present scope of this draft describes the testing and performance of encapsulants designed to reduce or eliminate the release of asbestos fibers from the matrix of friable spray- or trowel-applied asbestos-containing building materials.

The "draft" standard consists of two separate test protocols with acceptance criteria:

1. a series of laboratory tests which show whether an encapsulant is capable of acceptable performance on a specified asbestos-free[1/] matrix, and;

1/ This is necessary since EPA does not allow the use of asbestos in preparing laboratory test samples.

2. a series of tests to be conducted in the field at each location where encapsulation is being considered, which show whether an encapsulant is acceptable on the specific asbestos-containing matrix.

This ASTM draft standard does not provide a means for determining whether encapsulation or any other control technique is suitable for any particular installation of friable asbestos-containing material and does not give guidance for making such a determination. The purpose of this draft standard is to provide guidance for the selection of an encapsulant once the decision to encapsulate has been made. It is assumed that users of this standard have already made a decision to encapsulate friable asbestos-containing material and that this decision is appropriate.

The proposed test methods for laboratory testing are: cohesion and adhesion, penetration, deflection, surface abrasion, air erosion, fire resistance, surface burning, and surface impact. With regard to field testing, the proposed test methods are: adhesion and cohesion, penetration (for penetrating encapsulants only), and fiber release. The test protocols in this standard do not cover the permeability to water vapor of encapsulants when applied to friable materials, or the mildew and fungus resistance of encapsulants, or the ability of penetrating encapsulants to aid control of application amounts by tinting. These properties may be determined by other standard test methods.

For information about the status of the ASTM draft standard the reader is referred to ASTM headquarters[1/].

3.4.2 ASTM Standard E849

The ASTM Standard E849, Standard Practice for Safety and Health Requirements Relating to Occupational Exposure to Asbestos [15], was approved in April 1982. This standard is intended to be used for occupational exposures including mining, milling, transportation, manufacturing and product use. The scope excludes occasional work that may involve intermittent exposure and pathologically inert particulates such as certain asbestos cement dusts. Section 3.1 of the standard states that it is meant to "(a) protect against the development of asbestos related disease; (b) be measurable by techniques that are valid, reproducible, and available to industry and official agencies; and (c) be attainable with existing technology".

The maximum exposure to asbestos for a specific time required by the standard calls for the concentration of airborne asbestos particulates not to exceed permissible occupational environmental limits of 2.0 f/cc based on an 8 hour time weighted average and 10.0 f/cc based on peak levels. The fibers are defined as monitored particulates with an aspect ratio of at least 5:1, a minimum length of 5 μm, a maximum diameter of 3 μm, and the appearance of a fascine (bundle of sticks effect).

1/ American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

The ASTM Standard E849 includes annexes with mandatory information on characteristics of asbestiform minerals, epidemiology and toxicity tests, rationale for the 5:1 aspect ratio, midget impinger instrument for mineral dust sampling, and personal protective equipment.

4. EVALUATION OF ASBESTOS-CONTAINING MATERIALS IN BUILDINGS

It is necessary that a consistent approach be followed in determining the condition of asbestos-containing material in an agency's building inventory. The methodology presented below represents a compilation of procedures developed from a review of the literature, analysis of procedures used by Federal and local governmental agencies, and those found most effective in an asbestos survey NBS performed for GSA.

4.1 REGIONAL SURVEY

When an organization has a large inventory of buildings which are geographically dispersed, it is necessary to determine, on a regional basis, which buildings have friable asbestos-containing material and may require abatement action. This is necessary for setting priorities and establishing budgets.

Scope of Survey

A. A representative of the regional office who is knowledgeable of asbestos assessment should visit every building in the region to identify locations where asbestos-containing materials may have been applied. Samples of suspected materials should be taken from these locations for testing. Even though fireproofing and insulation containing asbestos were applied only in the period following World War II to the early 1970's, no building should be excluded from such a survey. Buildings constructed before and after this period of time may have undergone renovations where asbestos materials were used. Each floor including basements, penthouses, or attics should be visually inspected. Materials containing asbestos may be located in numerous areas of any building: (1) in open view on ceilings, walls or piping throughout the entire building; (2) in one particular room (computer, keypunch); (3) in corridors and staircases; (4) in restricted access areas such as mechanical rooms, or penthouses, or (5) in enclosed spaces such as air plenums above suspended ceilings or vertical air shafts.

B. Bulk samples of material suspected of containing asbestos should be analyzed to confirm its presence and to assist in assessing the potential airborne asbestos fiber level of each building. The general condition and the location of the material should be noted. Sampling techniques, including an inexpensive and simple field test for quickly determining whether asbestos is present in building materials, are discussed in more detail in section 4.3.

C. Based on data collected in A and B, buildings should be selected for detailed follow-up investigation as outlined in section 4.2.

4.2 BUILDING INSPECTION PROCEDURES

After it has been determined through the regional survey that a building has friable asbestos-containing material, a more thorough inspection should be made.

The following steps may be taken in determining the location, type and condition of asbestos materials needed to evaluate the building with regard to asbestos applications.

4.2.1 Discussion with Building Personnel

Maintenance and operations staff will probably be most familiar with the building and applications of asbestos-containing materials. They should be able to provide information on the special procedures followed in the building when working around asbestos-containing materials and building documentation (plans, specifications, etc.). Historical information relative to previous asbestos evaluations, abatement actions taken or planned, etc., can also be obtained from the staff.

4.2.2 Review of Plans and Specifications

Building construction records should be reviewed to determine where asbestos-containing materials may be located, to establish the type and concentration of asbestos in the material, and to assist in evaluating building systems which may affect airborne asbestos fiber levels. Since records may erroneously report either the presence or absence of asbestos, reliance on building records alone is not recommended.

4.2.3 Review of Previous Investigations and Abatement Actions

Many buildings have had previous asbestos investigations and/or abatement actions taken and this information should be reviewed. This historical perspective allows an evaluation of the condition of the material over time and would be vital in preparing future recommendations.

4.2.4 Walk-Through Inspection

The following can be accomplished during the inspection of the building:

a. compare as-built condition of the building to that shown on available plans and specifications;

b. determine location and condition of asbestos-containing materials with appropriate photographic documentation;

c. evaluate building systems which may affect airborne asbestos fiber levels (e.g., open air return plenums);

d. select portions of the building which may require follow-up sampling and evaluation; and

e. determine the characteristics of the building occupancy which may affect the selection of asbestos abatement actions (e.g., effect of temporary relocation of tenants).

4.3 SAMPLING TECHNIQUES[1/]

After material which may contain asbestos fibers is located in a building, it is necessary to first confirm its presence, and then to determine if asbestos fibers are being released to the air. Guidance for the sampling and analysis of asbestos-containing materials has been prepared by EPA [16].

4.3.1 Field Test for Asbestos[2/]

Kim and Kupen have developed an inexpensive and simple field test (K^2 test) for quickly determining whether asbestos is present in building materials [17]. The K^2 test is a color screening test that reveals the presence of the magnesium or iron found in asbestos. The test procedure consists of mixing a small sample of material with selected chemicals and reagents which cause the magnesium or iron to be released. These elements then react with the reagents to produce either a red color for iron or a blue color for magnesium. No color change means that neither iron nor magnesium is present and indicates the absence of asbestos. If magnesium or iron is present, a sample should be sent to a laboratory to confirm the presence of asbestos. If a test is negative, however, the probability of finding any asbestos by further testing is extremely low and does not warrant laboratory analysis [17].

While the validity and accuracy of the K^2 test has been shown by laboratory analysis, field experience has indicated the following problems[3/]:

A. Some field personnel feel uneasy doing the test because "tearing" of the bulk sample is involved, resulting in potential asbestos exposure even though precautions are taken (respirators are worn, wet samples are used, etc.).

B. Some nontechnical personnel collecting samples do not want the responsibility of screening and deciding.

4.3.2 Bulk Sampling [4,5,16]

Once suspected asbestos-containing material has been identified in a building, the entire building should be inspected for identical materials. If other forms of suspected materials which differ in texture, fiber type, or color (other than paint) are found, these should be noted as different material areas and sampled separately. After inspecting the building and taking samples, the samples should be analyzed by a laboratory. The remainder of this section

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1/ NBS has not evaluated the measurement methods discussed in this report and therefore neither endorses nor disapproves their adequacy.

2/ A description of the test method is available from Publications Dissemination, DTS, National Institute for Occupational Safety and Health, 4676 Columbia Parkway, Cincinnati, Ohio 45226.

3/ Private communication with test developer.

discusses the selection of an analytical technique, the selection of a laboratory, and practices to ensure quality of results.

4.3.2.1 Selection of an Analytical Technique for Bulk Samples [5]

Many materials suspected of containing asbestos consist of a mixture of asbestos and other components such as fibrous glass, rockwool, slagwool, woodpulp, and paper fibers. Bulk samples of building materials are analyzed by microscopic inspection to determine whether asbestos is present and, if it is present, in what quantities and types. Lentzen, et al. [18], discuss a statistical approach to evaluate precision and accuracy of laboratory measurements of asbestos in bulk insulation material. There are three possible fiber identification techniques: polarized light microscopy (also known as petrographic microscopy), x-ray diffraction, and electron microscopy.

Polarized light microscopy is the technique most widely used, primarily because the technique is well established and the analysis is relatively low in cost. The technique involves the identification of substances by their optical and crystallographic properties; an experienced microscopist can locate even small amounts of asbestos in bulk samples. Accuracy below five percent is questionable and should be regarded as a trace. Samples below five percent tend to be inhomogenous.

X-ray diffraction is a more expensive technique which involves exposing a small sample of the material to x-rays and identifying minerals by their unique diffraction patterns. The technique usually yields information with a high degree of diagnostic reliability. However, it is not suitable as an independent method of analyzing samples to determine whether they contain asbestos for two reasons. First, X-ray diffraction cannot differentiate between fibrous and nonfibrous forms of serpentine and amphibole minerals, and cannot positively identify a mineral as asbestiform. Second, it may fail to detect small concentrations of asbestos (less than two percent to four percent if fibers are not concentrated during laboratory preparation). For these reasons, X-ray diffraction should be used only as a supportive technique to confirm results achieved by polarized light microscopy.

The third microscopic technique is electron microscopy. Although specific and accurate fiber identification can be achieved using this technique, particularly if it is used in conjunction with polarized light microscopy and X-ray diffraction, the cost of electron microscopy is extremely high, and the availability of laboratories which can conduct the analysis is limited. Electron microscopy is not a precise method for determining asbestos concentration. Analytical methods of analysis recommended by EPA are polarized light microscopy with or without dispersion staining and X-ray diffraction [16]. EPA does not recommend electron microscopy as a method for analysis; its primary usefulness lies in its ability to resolve any ambiguities arising from the use of polarized light microscopy and X-ray diffraction. If data on the length, width, concentration, and species of mineral fibers are needed, microscopy methods are necessary for mineral fiber analysis. Because of the small size of the particles, electron microscopy is necessary [19].

Table 4.1 from reference [5] summarizes the advantages and disadvantages of the three bulk sample analysis techniques.

Table 4.1 Summary of Asbestos Bulk Sample Analysis Techniques[1/]

Method	Advantages	Disadvantages
Petrographic Microscopy (Polarized light microscopy)	Relatively rapid and low cost per analysis, suited for exact identification of minerals present and estimate of abundance	High level of operator training and experience required; fibers with diameters of less than 0.5 μm cannot be identified
X-ray Diffraction	Unambiguous mineral fiber identification, rapid fingerprinting of sample with permanent record	High investment in training personnel and capital equipment; may not detect minor fiber abundances (less than 2-4 percent), especially if other crystalline phases are present
Electron Microscopy	Absolute determination of fibers present and identification of mineral species	High equipment and analysis costs; highly trained operator required

[1/] Table taken from reference [5].

4.3.2.2 Selection of a Laboratory

The identification of asbestos in bulk materials is not a routine laboratory procedure. Only laboratories which are actively engaged in using polarized light microscopy or X-ray diffraction to determine whether asbestos is present in bulk samples should be considered for this service. GSA requires proof of qualifications of testing laboratory and personnel be submitted for approval by the contracting officer [12].

EPA sponsors an analytical proficiency program for bulk sample analysis with approximately 75 laboratories currently participating in the program [16]. EPA periodically sends these laboratories samples of materials with the asbestos content known only to the agency. EPA compares the results determined by the laboratories with the actual asbestos content of the materials. The results for commercial laboratories which participate in the program are available from

EPA by calling (800) 334-8571[1/]. EPA has published a procedure for evaluating the performance of laboratories which have not participated in the program [16].

In order to ensure that the laboratory has analyzed the samples according to the procedure requested, and to facilitate the recordkeeping process, it is important that complete reporting of the analytical results be obtained from the laboratory. A complete and signed report should be obtained from the laboratory and should include the following:

1. Sample identification number and name of requesting organization.

2. Analytical method used to analyze the sample.

3. Percent of each type of asbestos present.

4. Type and amount of fibrous material present in the sample.

4.3.3 Air Monitoring [4,5,16]

Air monitoring, currently the most widely used measurement method for determining airborne asbestos fiber levels, is subject to measurement inaccuracies inherent with the methodology employed. Also, it provides only an estimate of the actual number of fibers in the air at any given time while extent of fiber release may vary widely over time. Levels may vary depending on the level of the activities in the building, as well as changes in the building condition.

4.3.3.1 Guidance on Sampling Methods

Considering the current state-of-the-art, it is not possible to outline a statistically based approach for collecting and analyzing air samples in a building. Such approach would have to consider all relevant factors such as building construction characteristics, occupancy type, typical activities of occupants, etc. The following general guidance is provided in selecting an air sampling program.

Conditions under which air sampling should be scheduled in a building are: (1) normal occupant activity, (2) custodial activity, (3) routine maintenance near asbestos-containing materials, and (4) application of building modifications directly affecting asbestos-containing materials (e.g., movement of partitions, construction of floor penetrations). Sampling under "quiet" conditions, such as at night, may be misleading because asbestos fibers more likely would become airborne as a result of disturbance through human activity.

Reference [5] lists the following criteria as basic to any air monitoring program:

1/ Research Triangle Institute, Research Triangle Park, North Carolina.

1. Samples obtained should be representative of the airborne fibers at the sampling point.

2. Numbers of samples must be sufficient to compensate for the variation of concentration with time and space and represent "full shift" exposure to the worker.

3. Samples taken for short periods of time with low volume personal monitoring pumps can only be satisfactory in high dust concentrations where a measurable amount of asbestos can be captured.

4. Long period sampling instruments must be used in low concentrations to obtain environmentally significant samples.

5. Samples must be taken within the workers' breathing zone or in the immediate work areas, as well as outside of the controlled area, as necessary, to properly characterize airborne asbestos fiber levels.

6. All persons monitoring asbestos-containing material, as well as persons evaluating samples of the material, must be judged proficient in these disciplines, in accordance with generally accepted methods.

Locations and building activities where air monitoring may be conducted include:

A. Occupied Space (offices, medical, food preparation, etc.)

Monitoring devices for collecting personal samples should be placed in the breathing zone of persons who occupy the room during normal building activities. The exposed filter should face downward within the breathing zone.

B. Air Return Plenums and Vertical Shafts

In open air return plenums where structural members are coated with fireproofing containing asbestos, the air should be sampled for asbestos fibers periodically during normal building activities and when renovation or asbestos abatement projects are underway. Vertical shafts which return the air from the horizontal plenums to the main air supply rooms should also be sampled.

C. Maintenance Activities

Periodic samples should be taken in areas where maintenance activities are being conducted to determine whether excessive fiber release is occurring.

D. Building Renovation and Asbestos Abatement Activities

Air monitoring should be conducted during renovation projects which damage asbestos-containing material and during abatement projects. Area sampling should be done inside the sealed workspace, immediately

outside the workspace, near all major openings, and inside the clean room and decontamination room. Adjacent occupied space and air return plenums should also be monitored. Personal sampling of abatement workers should be conducted.

OSHA regulation 29 CFR 1910.1001 sets limits for permissible exposure to airborne concentrations of asbestos fibers for renovation and asbestos abatement activities (see appendix A).

4.3.3.2 Measurement Methods for Air Samples

Phase contrast microscopy is specified in section 1910.1001(e) of Title 29, Code of Federal Regulations, as the method of fiber content measurement of air samples (see appendix A). A sample is collected by drawing air through a membrane filter at a known rate. A segment of the filter is then mounted, treated chemically to make the filter membrane transparent, and examined using a special microscope reticle and counting procedure with phase-contrast illumination at 400 to 500 magnification. Particles are observed for shape and size. Results are presented as the number of fibers per cubic centimeter of air drawn through the filter. This method has limits on the fiber size range on which it can be used with only particles having a length-to-width (aspect) ratio greater than 3:1 and a length of 5 μm or greater counted as fibers (see figures 1.2 and 4.1). Secondly, reference [6] points out that fibers other than asbestos (e.g., cellulose, glass fibers) which are likely to be present in ambient air would be counted by phase contrast microscopy. Finally, the measurement method would miss very thin fibers of any type (<0.5 μm in diameter). It should be noted that substitution of another fiber measurement method, such as those listed below, would require a special interpretation by OSHA.

The electron microscopy method permits detailed examination and identification of asbestos fibers of all sizes. Either scanning electron microscopy or transmission electron microscopy is used. Magnification necessary to identify asbestos in its smallest dimension is within the range of these instruments. Fiber size range detected by electron microscopy is all inclusive while that seen optically by phase-contract microscopy is much more limited. In some cases, the distribution of fiber length will fall below 5 μm, producing a zero fiber count by phase contrast microscopy, but the same sample may have a significant fiber count when examined by electron microscopy. Analysis by electron microscope is extremely expensive (maybe 15 times costlier than phase contrast microscopy) and time-consuming, and the number of laboratories which can conduct the analysis is limited.

An EPA provisional method [20] is also used for the measurement of airborne asbestos concentrations. The main features of this method include depositing an air sample on a polycarbonate membrane filter, examining an electron microscopy grid specimen in a transmission electron microscope and verifying fiber identity by selected area electron diffraction.

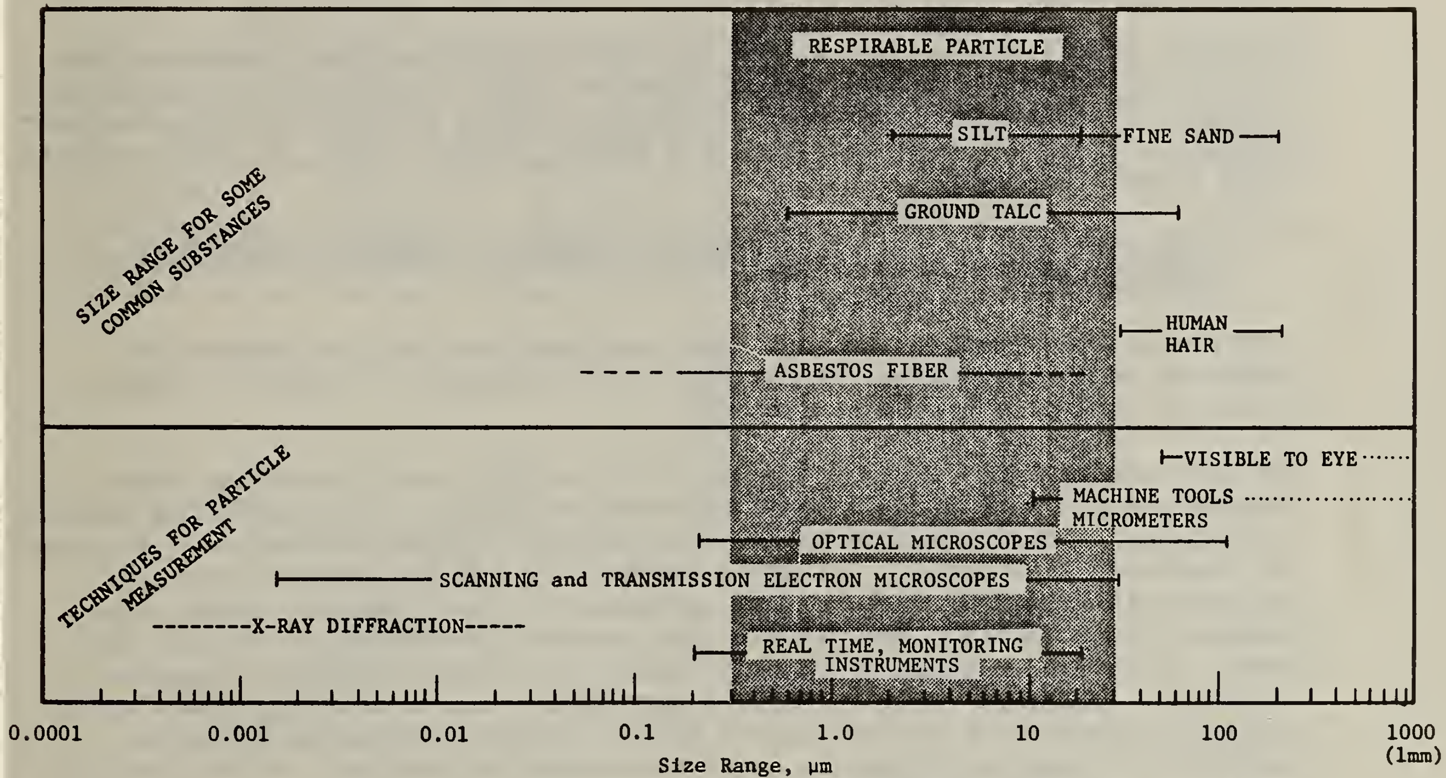

Figure 4.1 Comparison of fiber size range and techniques for particle size measurement 1/

1/ Taken from reference [5].

4.3.3.3 Comparison of Air Sampling Results With Federal Regulations

Specific guidelines are not currently available for occupant exposure to airborne asbestos fibers in buildings having in-place asbestos-containing materials (fireproofing, insulation, etc.) that are not disturbed by maintenance, renovation, or removal activities. What the limit should be is unknown, but subject to much debate. As noted previously, the EPA has developed some guidelines for schools [3,4,21], but air sampling is not included.

The OSHA regulation 29 CFR 1910.1001 (appendix A) has set the permissible exposure level for asbestos fibers at 2.0 fibers (longer than 5 μm) per cc of air on an 8 hour TWA basis for situations where work in the building disturbs the in-place materials containing asbestos. Allowable concentrations of airborne asbestos fibers when work is taking place is 10.0 fibers (longer than 5 μm) per cc of air.

OSHA also has issued an instruction for Minimum Airborne Fiber Concentrations for Initiating and Continuing Asbestos Medical Examinations [22]. The enforcement guidelines require that medical examinations be given for an asbestos concentration equal to or greater than 0.1 fibers, longer than 5 μm, per cc of air on an 8 hour TWA basis.

4.4 AVAILABLE METHODS FOR EVALUATING THE POTENTIAL ASBESTOS EXPOSURE IN BUILDINGS[1/]

Several asbestos exposure indexes have been developed for application in buildings which are claimed by the developers to provide a basis for making decisions regarding abatement actions.

EPA published a draft guidance document [4] in 1979 which identified eight factors which should be considered by school officials when determining whether a hazardous condition exists due to the presence of friable asbestos. They are; (1) condition of material, (2) water damage, (3) exposed surface area, (4) accessibility, (5) activity and movement, (6) air plenum or direct air stream, (7) friability, and (8) asbestos content (as determined by bulk analysis). This was followed by the development of a "Draft Asbestos Exposure Assessment Algorithm" [23] which is a methodology for obtaining a quantitative exposure number which can be used to select various options for asbestos control. EPA has the algorithm under evaluation and has not, as this writing, published it in final form.

The algorithm was prepared taking into account fiber characteristics, asbestos risk factors, and experience with school exposure situations. It does not consider factors such as duration of exposure and population characteristics.

[1/] NBS has not evaluated these methods and neither endorses nor disapproves their application. They are included for the reader as a guide for the assessment and abatement of asbestos-containing materials. It is recommended that the reader contact the organizations which developed these evaluative methods if additional information is required.

There are three steps in applying the guide: (1) the eight factors are assigned a numerical value corresponding to their proper description; (2) the numerical values are combined by a mathematical formula to produce the exposure number; and (3) the exposure number is compared to the corrective action scale.

GSA has taken the EPA algorithm developed for schools and modified it to be more representative of highrise buildings which are owned and leased by the Federal Government [24].

The Navy has developed a hazard index (see section 3.3.3) with the assumptions that potential health hazards associated with the presence of friable asbestos depends on; (1) the level of exposure, (2) the number of persons exposed to asbestos fibers; and (3) the duration of exposure [5]. The level of exposure depends on the percent of asbestos fiber as determined by bulk analysis, friability of the material, and level of activity in the space where asbestos is located. The index recognizes that as the number of people exposed to a particular concentration of airborne asbestos fibers increases, the chance of some adverse effects also increases. Therefore, the asbestos hazard index number will be greater where a large number of people are exposed than for a situation where lesser numbers of people are exposed. The length of time an individual is exposed to a given level of asbestos fibers contributes to the likelihood of adverse health effects. Therefore, the hazard index number will be greater when the number of hours that individuals are exposed in a year is greater. Application and testing of this index is underway in U.S. Navy facilities.

5. ASBESTOS ABATEMENT TECHNIQUES [5]

Selection of the appropriate corrective measure to accomplish the most efficient long-term asbestos abatement solution should be based on the condition of the asbestos-containing material, its location, the function and occupancy of the work area, and the cost. Each building area containing such material should be considered separately in evaluation and selection of abatement techniques.

In the selection of a corrective measure or technique, it should be determined whether the situation requires entire removal of asbestos materials to eliminate exposure or merely control of the exposure by containment methods. Encapsulation and enclosure are containment methods that only prevent or reduce exposure to asbestos-containing material but do not eliminate the source. Consideration should be given to the effectiveness and permanency of containment methods. The source of airborne asbestos fibers may reappear because of inadequate long-term performance of corrective abatement techniques or materials and damage to corrected areas caused by repair or remodeling activities. The two approaches to the control of airborne asbestos fiber levels may be either interim or long-term measures. Two important considerations in the selection of either of these measures are the level of deterioration of the asbestos-containing material and function of the material. For example, if fireproofing has deteriorated to the point that the required protection is no longer provided to structural members, interim measures may not be a proper selection even though very feasible.

5.1 INTERIM CONTROL MEASURES

EPA has prepared guidelines for establishing and maintaining a management system for asbestos-containing materials in schools [21]. The document recommends that an asbestos management system should be implemented for each building with friable asbestos-containing material in order to control the level of airborne asbestos fibers and to coordinate related activities. During the period between identification and resolution of an asbestos exposure problem, the management system team should establish an educational and training program and procedures that will reduce levels of airborne asbestos fibers by control of maintenance, custodial, and repair activities. If a containment abatement measure is selected, a continuing inspection and monitoring program should be initiated. The management system team should offer to oversee the engineering program and should be composed of members from the buildings' architectural/engineering staff, planning and estimating office, building maintenance shop, safety office, and if available, an industrial hygienist.

The management system program should include as a minimum, the following activities:

- An educational program to inform the occupants of the building of the asbestos-containing materials.
- A recordkeeping system on file with the building's architectural/engineering staff and with the building's maintenance personnel.
- Records of the location of the asbestos-containing materials and of inspections and reevaluations of the conditions of these materials.

- Periodic surveys for detecting any changes in the condition of the asbestos-containing materials.

- Maintenance work procedures to limit the release of airborne asbestos fibers.

- Proper dust control procedures for the custodial staff.

In the interim period, the level of airborne asbestos fibers may be reduced significantly during essential custodial work if oil-treated dust mops and cloths or damp mops are used instead of dry dusting and sweeping. Vacuuming should be carried out using high efficiency particulate air (HEPA)[1/] filtered vacuum cleaners or other systems to effectively filter asbestos fibers. An industrial hygienist can advise and approve proper custodial methods and equipment to reduce levels of airborne asbestos fibers.

5.2 LONG-TERM CONTROL MEASURES

The long-term control measures include containment and removal methods. Containment methods include encapsulation and enclosure, and removal may be accomplished by wet or dry methods. These long-term methods can be used separately or in combination in a building. A brief description of these methods follows:

- Encapsulation - asbestos-containing material is coated or impregnated with a bonding agent or sealant which restricts release of fibers.

- Enclosure - asbestos-containing material is separated from the building work area environment by barriers such as impervious sheathing.

- Wet Removal - asbestos-containing material is removed using amended water (wetting agent) and disposed of by burial in sealed containers at an EPA-approved landfill site.

- Dry Removal - asbestos-containing material is removed dry and disposed by burial in sealed containers at an EPA-approved landfill site.

Removal or containment of asbestos-containing material generally requires specialized equipment and persons involved in working with the material who should be made aware of EPA, OSHA, and local regulations and standard procedures through training. Superintendents, foremen, and contract inspectors should check for compliance with regulations and proper work practices.

5.2.1 Containment

Containment of asbestos-containing material by encapsulation or enclosure systems in general takes less time than removing the material and is less

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[1/] HEPA filters in conformance with ANSI Z9.2-1971," Design and Operation of Local Exhaust Systems."

expensive, especially if replacement of material can be avoided. It must be understood that the airborne asbestos fiber source remains and that damage, deterioration, or failure of the protective system may result in recurrence of asbestos fiber release. Therefore, the selection of containment as a control measure requires that a periodic inspection program be established. This is necessary to ensure that the protective system maintains its integrity over long periods of time, especially over the expected service life of the protective system. If a containment system is selected, strictly controlled maintenance and custodial activities are required for the life of the building, as long as asbestos-containing material is present. Problems may recur later when a building is renovated or demolished if asbestos-containing materials are damaged. Encapsulation and enclosure measures are discussed below.

5.2.1.1 Encapsulation

Encapsulation involves sealing asbestos-containing materials with an appropriate coating. Sealing of surfaces of asbestos-containing materials is accomplished by applying a coating material that will envelop or coat the fiber matrix, restricting the release of fibers, and afford protection against contact disturbance. Encapsulation should not be chosen if the asbestos-containing material is not well bonded to the substrate.

Sealants are of two types: those that penetrate the sprayed asbestos material and those that cover or bridge the material with a tough protective coating. Each of the two types of sealants has some specific advantages. Penetrating sealants cause improved cohesive strength and impact resistance of friable materials when the matrix is sufficiently saturated. Penetrating sealants also exhibit varying degrees of penetration from about 13 to 32 mm (1/2 to 1-1/4 in). Some may penetrate to the substrate or structural member to which the friable asbestos is applied. The bridging type of sealants exhibit, in general, better flexibility and abrasion resistance than the penetrating types and form a continuous surface membrane over the asbestos-containing material. Sealants currently available include water-based latex polymers, water-soluble epoxy resins, and organic solvent-based polymers. See section 3.4.1 for discussion of an ongoing ASTM standards activity on encapsulating agents for asbestos-containing material.

Encapsulation can be a practical method to control the release of asbestos fibers, but certain limitations make it useful only in a relatively small number of cases. Encapsulation is often advisable in situations where the asbestos-containing material is virtually impossible to remove such as on denser, harder materials generally referred to as trowelled on or cementitious materials [25]. EPA estimates that encapsulation is an appropriate control technique in no more than 10 to 15 percent of all cases where asbestos-containing material requires corrective action [25].

Encapsulation of friable asbestos-containing material should not be considered when the surfaces of these materials are:

- accessible to personnel (low ceilings, corridors, or stairwells);

- potentially subject to physical damage (by vandalism, sports activities, routine maintenance, or general use of building);

- potentially subject to water damage (history of roof leaks, plumbing problems, or accumulation of condensation); or

- potentially subject to forceful structural vibrations (rooms below or adjacent to heavy moving equipment or sports activity).

The best way to determine whether an encapsulant will perform on a given surface is to field test it by applying it to a small section of the surface. Several encapsulants should be field tested in this manner before a final decision is made regarding which one to select.

The use of sealants is governed by the characteristics of the friable material surface. Integrity of an encapsulated surface depends upon the bond between the material and substrate to which it was applied and the cohesive strength of the friable material. A sprayed ceiling, for example, with initially poor adhesion to a smooth, hard structural ceiling surface, may result in bond and shear failure of the total thickness of sprayed asbestos containing the applied sealant.

5.2.1.2 Enclosure

Enclosure of sprayed asbestos-containing material involves placing an impervious barrier between the material and areas of building occupancy. These enclosures could be placed either on walls or ceilings. Depending upon the integrity and type of barrier system, fiber fallout will occur only behind the barrier, and exposure outside the barrier will be greatly reduced. Entry into these enclosed areas requires protection of personnel and fiber containment precautions.

In selecting an enclosure system, consideration must be given to existing plumbing, electrical or mechanical systems which require accessibility for maintenance, repair or renovation. If the sprayed asbestos-containing material behind the enclosure is disturbed during maintenance on heating, ventilating, lighting, or plumbing systems, asbestos fibers may be released into the building, especially if it is an open air return plenum. Where possible, all utilities should be removed and rerouted from the enclosure space, and, when feasible, access should not be built into this space. The space behind a barrier system should not connect with an air plenum, and air from the enclosed space should not circulate within the occupied building unless a HEPA filtration system is installed for cleaning return air. Fire sprinkler systems may require relocation.

Like encapsulation, enclosure reduces the potential for dispersal of airborne asbestos fibers but does not eliminate the source and poses similar problems as encapsulation during building renovation or demolition. Enclosure of asbestos-containing material can be selected as a control measure, provided that the material will not be expected to be subjected to: (1) frequent damage during routine maintenance activities; (2) water damage; and (3) condensation buildup.

5.2.2 Removal

Removal of asbestos-containing material provides a long-term solution by elimination of the fiber source. Removal of friable asbestos material poses significant problems of worker protection, prevention of environmental contamination, and considerable interruption of building activities. Replacement with asbestos-free material must also be considered.

Removal of sprayed asbestos material may be considered [5] when any one of the following conditions is present:

- The material is friable and significantly deteriorated or damaged.
- The material is accessible and potentially subject to damage by vandalism or activities in the space.
- The material will be damaged during routine maintenance activities.

Critical factors which must be considered in the decision to remove sprayed asbestos-containing material include building characteristics, inability to eliminate exposure in another way, surfaces to which the material is applied, and cost. Asbestos-containing material may be removed by dry or wet methods.

5.2.2.1 Dry Removal

Dry removal of asbestos-containing material is not recommended by EPA, but may be necessary if unavoidable damage to building components, utility systems, and equipment would occur through the use of water amended with a wetting agent or if temperatures are below freezing [5]. If it is necessary to use the dry removal technique, extreme caution must be exercised to prevent contamination of workers, of areas outside the controlled area, and of the environment from the uncontrolled release of asbestos fibers. If well-managed, however, dry removal can be successfully performed. Written permission from EPA is required for dry removal.

5.2.2.2 Wet Removal

Airborne asbestos fiber levels in removal operations may be reduced by using wet removal instead of dry removal [5]. Wet removal is based upon the ability of water to lower both the friability of asbestos-containing material and the airborne concentration of released fibers, thus reducing airborne asbestos levels. Because of the additional weight, released fibers settle rapidly. Use of plain water may not be entirely satisfactory because of slow penetration, incomplete wetting, and runoff. Even with extensive soaking, areas of dry material will remain. Runoff is not only a safety and cleanup problem but can cause corrosion on metal parts of equipment and electrical systems as well as damage to floor surfaces (peeling of tile). The resulting slurry can also be transported by foot traffic to nonremoval areas, where fibers will reentrain following evaporation of the water.

Water penetration into a fiber matrix may sometimes be significantly increased with a wetting agent or surfactant which reduces the surface tension of water

droplets. Water amended with a wetting agent is commonly used by fire departments, industry, and agriculture. This wetting technique reduces the amount of water needed for saturation, increases cohesiveness of the fiber matrix, and increases the probability of individual fiber wetting. Use of amended water can reduce fiber counts by more than 90 percent as compared to dry removal. This reduction of fiber contamination within the work area not only reduces potential worker exposure and significantly improves working conditions, but relieves some of the dependence upon containment barrier systems in confining fibers to the removal area. Written permission from EPA is required for wet removal [5].

5.3 GUIDELINES FOR SELECTING APPROPRIATE ABATEMENT TECHNIQUES

Guidelines for selecting appropriate abatement techniques are presented in table 5.1. This table contains a summary of corrective methods in addition to information about the advantages and disadvantages of each method, and conditions for which each method is appropriate or inappropriate.

In addition to the information presented in table 5.1, the following additional factors should be considered in the selection of control measures.

- If the material is removed and fireproofing/thermal/sound insulation requirements still exist, material with similar performance characteristics must be applied.

- If the asbestos-containing material is accessible below the (2.7 m) 9-ft level on walls, the material will be subject to future accidental or intentional contact and damage. However, in warehouses, gyms and similar facilities, the level to which material is subject to contact and damage is higher than the (2.7 m) 9-ft level.

- If the asbestos-containing material is not removed, the problem must be addressed at the time of demolition.

- If an enclosure system is used, thermal insulating material will still be functional. Condensation problems and water problems, however, may still occur.

Table 5.1 Guidelines for Selecting Appropriate Abatement Techniques [5, 21]

Method	Advantages	Disadvantages	When Appropriate	When Inappropriate
Encapsulation	Controls exposure without removal of asbestos.	Asbestos source remains. Fireproofing, acoustical, or thermal qualities may be reduced.	Removal not feasible.	Removal feasible. Material has poor adhesive or cohesive strength. Weight of sealant may cause delamination.
	Usually most rapid and economical.	If material is damaged or deteriorating, additional weight of the sealant may cause delamination.	Material still retains bonding integrity.	Material is deteriorating or severely damaged.
		Management system required; precautions necessary to prevent damage during maintenance of renovation	Damage to material not probable.	Damage to material is probable.
		Continuing inspections required to check for damage to encapsulated surface.	Limited accessibility of material.	Water damaged materials. Materials are more than one inch thick.
		Maintenance of damaged or deteriorating encapsulated surfaces required.	Complex surfaces to be covered.	In rooms which are subjected to high vibration.
		Encapsulated material is difficult to remove.	Economic or time advantage.	
Enclosure	Controls exposure.	Asbestos source remains.	Removal not feasible.	Removal feasible. Damaged or deteriorating material causing high levels of fiber fallout.
	May be rapid, economical uncomplicated method.	Fiber fallout continues behind enclosure.	Disturbance or entry into enclosed area not likely.	Water damaged materials.
		May be costly if enclosure disturbs functions of other systems (e.g., enclosure may require lighting and plumbing changes).	Economic advantage.	Damage to enclosure likely. Entry into enclosure probable for repairs and maintenance.
		Management system required; precautions necessary for entry into enclosure for maintenance or renovation.	Material is accessible.	Continuing inspection and maintenance of enclosure doubtful.

Table 5.1 (Continued)

Method	Advantages	Disadvantages	When Appropriate	When Inappropriate
Enclosure (continue)		Continuing inspection required to check for damage to enclosure system. Maintenance of damaged enclosure system required.		
Wet Removal (Must obtain EPA approval)	Eliminates asbestos source.	Usually one of the most costly and complicated methods.	High exposure.	Removal is not feasible because of cost, location of material, and kind of surface to which material has been applied (e.g., removal of material from complex surfaces such as pipes, lines, and ducts).
	Ends exposure possibility.	Usually one of the most time-consuming methods. Replacement with substitute material may be necessary.	Material is deteriorating or damaged. Material is accessible.	When temperature is below freezing. Corrosion a problem.
Dry Removal (Must obtain EPA approval)	Eliminates asbestos source.	Usually one of the most costly and complicated methods.	High exposure.	Removal is not feasible because of cost, location of material, and kind of surface to which material has been applied (e.g., removal of material from complex surfaces such as pipes, lines, and ducts).
	Ends exposure possibility.	Usually one of the most time-consuming methods. Replacement with substitute material may be necessary. Extremely high potential for worker exposure.	Material is deteriorating or damaged. Material is accessible. Temperatures are below freezing during removal operations. Corrosion of metallic connectors is of major concern.	When wet removal is appropriate.

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APPENDIX A - SUMMARY OF EPA AND OSHA ASBESTOS REGULATIONS[1/]

EPA REGULATIONS PERTAINING TO ASBESTOS

The U.S. EPA Regulations contained in Title 40, Code of Federal Regulations, Part 61, as amended, applicable to asbestos removal operations are summarized below:

Subpart A - General Provisions

This subpart contains definitions (61.02), regional EPA office addresses (61.04), waiver information (61.10), (61.11), and other pertinent information.

Subpart B - National Emission Standard for Asbestos

Section	Content
§61.21 Definitions	Terms relating to asbestos material, visible emissions, demolition, friable asbestos material, renovation, wetting, removal, stripping, and waste material are defined in this section.
§61.22 Emission standard, work practice requirements	Contains information on application of standards, notification requirements, stripping of friable asbestos material, wetting, exhaust ventilation systems, restriction of spraying of asbestos containing material, waste material handling and labeling, and disposal regulations including site requirements. Specifies the applicability of standard to stripping or removal of asbestos materials of more than 80 meters (260 feet) of covered pipe, or 15 square meters (160 square feet) of friable asbestos materials used to cover a structural member. Procedures to prevent emissions are described: adequate wetting, local exhaust ventilation systems, proper movement and handling, and exceptions to wetting requirements. Spraying of over one percent asbestos material on structural members is prohibited. Waste disposal methods in renovation shall not produce visible emissions: waste material will be placed in locktight container while wet, and disposed of in sites in accordance with provisions of §61.25.

[1/] Taken directly from reference [5].

§61.25 Waste disposal sites	This section contains regulations on emissions access restrictions, sign posting, and operating methods for asbestos waste disposal sites.

Amendments to 40 CFR, Part 61, have been proposed and are found in the Federal Register of Wednesday, March 2. 1977. The proposed amendment resolve certain ambiguities and omissions in the present standard.

The applicability of regulations on renovations, removing, and stripping asbestos is broadened by deletion of phrases which limit application of the regulation to asbestos sprayed for insulation and fireproofing only. The proposed changes would enable the terms to cover all sprayed friable asbestos material, for whatever the intended purpose.

The amendment also clarifies the definition of structural member, and specifically includes nonload-supporting members such as ceilings and walls in the scope of the regulation.

OSHA REGULATIONS PERTAINING TO ASBESTOS

Applicable regulations of the Occupational Safety and Health Administration U.S. Department of Labor are contained in Title 29, Code of Federal Regulations, Part 1910. Regulations specific to asbestos removal or stripping are contained in section 1910.1001 *et seq*. are summarized below:

Section 1910.1001	Content
(a) Lists definitions.	Definitions of asbestos and asbestos fibers, size limitation of 5 micrometers or longer.
(b) Sets limits for permissible exposure to airborne concentrations of asbestos fibers.	Eight-hour time-weighted average TWA: two fibers, longer than 5 micrometers, per cubic centimeter of air (f/cc). Maximum concentrations: 10 f/cc.
(c) Methods of compliance, recommend methods to meet limits for exposure.	(1) Engineering methods: isolation, enclosure, ventilation, dust collection, should be used to meet the exposure limits.
	(2) Worker protection: Wet methods will be used, insofar as practicable, to prevent the emission of fibers in excess of the limits.
	(2)(iii) This section lists specific requirements for both respiratory protection and special clothing for removal workers.

(d) Personal protective equipment is specified for various conditions.	Respiratory protective equipment and special clothing are required whenever the exposure limits can reasonable be expected to be exceeded. Equipment approved by the agency is referenced. Respiratory protection: (d)(2)(i) Concentrations up to ten times the allowable limit (20 f/cc TWA, or 100 f/cc ceiling limit): air purifying respirator. (d)(2)(ii) Concentrations up to 100 times the limit (200 f/cc TWA, or 1000 f/cc ceiling limits) require powered air purifying respirator. (d)(2)(iii) Concentrations above 100 times the limit require type "C" supplied air respirator, continuous flow or pressure demand class. (d)(3) Special clothing shall be provided if limits are exceeded. Includes coveralls, head coverings, foot coverings. When clothing requirement is met, laundering service or disposal should be provided.

Section 1910.1001	Content
(e) Method of measurement of fiber concentrations is defined.	Determinations of airborne concentrations of asbestos fibers shall be made by the membrane filter collection method with phase contrast microscopy.
(f) Specific procedures of measurement and monitoring	Personnel monitoring, environmental monitoring, and frequency of monitoring are covered.
(g) Caution signs and labels are defined.	Specifications and use of signs are outlined. Posting of work sites and use of caution labels on asbestos material are described.
(h) Housekeeping to reduce exposure and waste disposal methods are described.	Cleaning of all objects of accumulated asbestos debris, and sealing in impermeable, sealed containers.
(i) Specifies recordkeeping and requirements for maintenance and retention of records.	Employer records on exposure. Time requirements and record disposition are covered. Records of monitoring should be retained for three years.

(j) Lists medical examination requirements.	Applicability, specific requirements, frequency of medical evaluations. Annual and termination examination requirements are listed.

APPENDIX B
REGIONAL OFFICES OF THE U.S. ENVIRONMENTAL PROTECTION AGENCY AND THE OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION

EPA REGIONAL OFFICES

Region I
Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island and Vermont
John F. Kennedy Federal Building
Room 2303
Boston, Massachusetts 02203
(617) 223-7210

Region II
New York, New Jersey, Puerto Rico, Virgin Islands, and Canal Zone
Federal Office Building
26 Federal Plaza
New York, New York 10007
(212) 264-2525

Region III
Deleware, District of Columbia, Maryland, Pennsylvania, Virginia, and West Virginia
Curtis Building
Sixth and Walnut Streets
Philadelphia, Pennsylvania 19106
(215) 597-9814

Region IV
Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee
345 Courtland St., NE
Atlanta, Georgia 30308
(404) 881-4727

Region V
Illinois, Indiana, Minnesota, Michigan, Ohio, and Wisconsin
230 South Dearborn Street
Chicago, Illinois 60604
(312) 353-2000

Region VI
Arkansas, Louisiana, New Mexico, Oklahoma, and Texas
First International Building
1201 Elm Street
Dallas, Texas 75270
(214) 749-1962

Region VII
Iowa, Kansas, Missouri, and Nebraska
324 E. 11th Street
Kansas City, Missouri 64106
(816) 374-5493

Region VIII
Colorado, Montana, North Dakota, South Dakota, Utah, and Wyoming
1860 Lincoln Street
Denver, Colorado 80295
(303) 837-3895

Region IX
Arizona, California, Hawaii, Nevada, Guam, American Samoa, Trust Territory of the Pacific
215 Fremont Street
San Francisco, California 94105
(415) 556-2320

Region X
Alaska, Idaho, Oregon, Washington
1200 Sixth Avenue
Seattle, Washington 78101
(206) 442-1220

OSHA REGIONAL OFFICES

Region I
Connecticut, Maine, Massachusetts,
New Hampshire, Rhode Island
and Vermont
16-18 North Street
1 Dock Square Building
Boston, Massachusetts 02109
(617) 223-6712/3

Region II
New York, New Jersey, Puerto Rico,
Virgin Islands, and Canal Zone
1515 Broadway
(1 Aster Plaza)
New York, New York 10036
(212) 399-5941

Region III
Deleware, District of Columbia,
Maryland, Pennsylvania, Virginia,
and West Virginia
Suite 2100
Gateway Building
3535 Market Street
Philadelphia, Pennsylvania 19104
(215) 596-1201

Region IV
Alabama, Florida, Georgia, Kentucky,
Mississippi, North Carolina,
South Carolina, and Tennessee
Suite 587
1375 Peachtree St., NE
Atlanta, Georgia 30309
(404) 881-3573

Region V
Illinois, Indiana, Minnesota,
Michigan, Ohio, and Wisconsin
Room 3263
230 S. Dearborn Street
Chicago, Illinois 60604
(312) 353-4716/7

Region VI
Arkansas, Louisiana, New Mexico,
Oklahoma, and Texas
Room 602
555 Griffin Square Building
Dallas, Texas 75202
(214) 749-2477

Region VII
Iowa, Kansas, Missouri, and Nebraska
Room 3000
911 Walnut Street
Kansas City, Missouri 64106
(816) 374-5861

Region VIII
Colorado, Montana, North Dakota,
South Dakota, Utah, and Wyoming
Room 15010
Federal Building
1961 Stout Street
Denver, Colorado 80294
(303) 837-3883

Region IX
Arizona, California, Hawaii, Nevada,
Guam, American Samoa, and
Trust Territory of the Pacific
P.O. Box 36017
9470 Federal Building
450 Golden Gate Ave.
San Francisco, California 94102
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Federal Office Building
Seattle, Washington 98174
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10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)*

This report presents guidelines for the assessment and abatement of asbestos-containing materials in buildings based on available information. Background information is given on the history and use of asbestos-containing products in buildings, and regulations pertaining to their use. Included are control measures for buildings containing asbestos materials, procedures for determining condition of the materials, and abatement techniques for containment and removal. A summary is presented of recent guide specifications and standards developed by industry, government agencies, and a standards organization which are related to asbestos-containing materials in existing buildings. These documents include guidance for the control, assessment, and abatement of such materials.

12. KEY WORDS *(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)*

abatement of asbestos; asbestos; buildings; fireproofing; insulation; regulations; structural steel

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